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MARYLAND DEPARTMENT OF STATE PLANNING

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Investigation of Application of ERTS-1 Data to Integrated State Planning in Maryland

FINAL REPORT

Maryland Department of State Planning
Earth Satellite Corporation

JANUARY 1975

APPLICATION OF ERTS-1 DATA TO INTEGRATED STATE PLANNING IN THE STATE OF MARYLAND

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NASA GODDARD SPACE FLIGHT CENTER
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APPLICATION OF ERTS-1 DATA TO INTEGRATED STATE PLANNING IN THE STATE OF MARYLAND

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16. Abstract

An experiment was conducted to test the utility of ERTS-1 and other remotely sensed data within an application setting - a comprehensive Statewide General Land Use Plan program in the State of Maryland. Several tasks were performed to evaluate potential application areas: land use mapping, studies of critical areas and specific land use problems, and land capability/suitability analysis.

ERTS-1 data was evaluated in each of the tasks with the following positive results: utility as regionally comprehensive data source for extracting generalized, small scale information, e.g. geology and land use/cover; a potential for monitoring ephemeral and/or highly dynamic phenomena, such as detection of bare ground areas for monitoring urban growth, mapping of forest defoliation, detection of previously unmapped fractures or lineaments, and monitoring of industrial effluents. An ERTS-1 color mosaic of the State demonstrated unique capability as an interagency and public communicative media. In addition, ERTS also provided an information base and data input to Maryland's Automated Geographic Information System (MAGI).

Some planning tasks, however, could not be satisfied with ERTS data. Reasons are inherent to both the user community and the data. For example, Levels III and IV of the U.S.G.S. land use/cover classification system could not be consistently obtained from ERTS-1 data to supply the needs of the Maryland State planning community which uses this level of information for many specific planning tasks, for constructing and maintaining selected data in the MAGI system, and for distributing planning data to lower jurisdictions. Whereas it was determined that conventional remote sensors can supply much of this information, ERTS data were evaluated as inadequate for some of these planning information needs.

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PREFACE

The study reported herein - on the application of ERTS-1 and other remotely sensed data to State Planning in Maryland - is in many ways a more severe test of the capabilities of these data than would be possible in most other states in the U.S.

Maryland is a small, densely settled and diverse landscape. It is highly urbanized and industrialized, has great tracts of suburban sprawl, an increasing demand for second home and resort-area development, yet at the same time has a long established small farm agriculture and forest products industry. Its lengthy sea and bay shorelines support both major commercial and recreational fishing industries. Small communities in its western mountains and coastal areas support lumber, orchard and small-farm agricultural industries which are now being assailed by second home developments.

This broad range of land uses weaves a fine and complicated pattern throughout the State; the fabric is influenced by an equally diverse range of geographic regions and landforms.

The insitututional framework is equally diverse and strong - with established planning bodies at municipal, county, regional, and state levels. Each has distinct but interrelated demands for detailed information.

Finally, the range and quality of background data on the natural and cultural environment in the form of detailed statistics, large scale maps of soils, forest lands, infrastructure, housing stock, water quality and so on, exceeds that available in all but a handful of other states.

All of these factors reduce the scope within which ERTS-1 might viably compete on the Maryland scene. Thus it is fair to conclude that Maryland may be regarded as a most exacting test case for ERTS-1 and that in environments of less complexity, much higher use levels will be realized for ERTS-1.

As ERTS studies progress, we expect to see a regional filtering of results which reflect the physical and institutional environment as much as the inherent capability of ERTS. A valid perspective of the applications of ERTS in planning problems will require samples throughout the United States. While the results contained within this study, most importantly the recommendations, are applicable nationwide they perhaps more realistically reflect conditions that prevail most frequently within the Northeastern and Southeastern states and the San Francisco - San Diego corridor in California.

They are presented here for the consideration, and hopefully, the use of those inclined to direct 20th century technologies to the problems and opportunities of man and his progeny.

CHAPTER I

SUMMARY AND RECOMMENDATIONS

The Maryland Department of State Planning/Earth Satellite Corporation experiment entitled "Application of ERTS-1 Data to Integrated State Planning in the State of Maryland," was a joint public agency - private corporation effort to examine, test, and apply remotely sensed data from satellites and other sensors in the realistic setting of a statewide General Land Use Plan program. In this program, three types of information were required: land use information, land management information applied to critical areas and problems, and information to determine the capability and suitability of land for different uses. Underlying this requirement of the Plan was a need for the Department of State Planning to make this information available to functional agencies of Maryland's State government as well as regional and local planning agencies.

Objectives were derived from the planning program specifying the general areas to which remote sensing was to contribute. Determining and evaluating the utility of each type of remotely sensed data was based on each sensor's ability to meet these objectives. Results that proved a particular type of information capable of operational use in the program caused planning procedures to be revised in a number of instances. In brief, the objectives focused on the above general goal by including the development of techniques related to the extraction and display of remotely sensed information, and the development of interpretation, earth sciences, and decision models to make remotely sensed data useful in integrated planning. "Short-term" objectives were to formulate methods and procedures for interpreting and immediately using several types of data in the Maryland General Land Use Plan. "Long-term" objectives were geared toward the general statewide planning program, seeking to establish a statewide geobase information system based in part on satellite and other remotely sensed data (including collateral information), the development of the necessary operational systems and models, and the establishment and expansion of a continuous role for remotely sensed data in planning programs. The latter objective, in particular, required an extensive effort to communicate and diffuse the benefits of remotely sensed data to a variety of planning agencies and planning "publics".

In some instances, results of the experiment indicated that additional effort was required to make remotely sensed data operational. Funds were provided in some cases to extend work in the project. These funds included those from the U.S. Department of Housing and Urban Development, the State of Maryland, and several local and special purpose organizations.

The Principal Investigator was Edwin L. Thomas of the Department of State Planning, and the Co-investigator was Dr. David S. Simonett of

Earth Satellite Corporation. Two consultants and consulting organizations, Mr. Harold F. Wise, and the Environmental Systems Research Institute of Redlands, California, and the staffs of the two principal organizations, provided the necessary support.

REVIEW OF SIGNIFICANT RESULTS

ERTS-1 data was evaluated along with conventional remote sensing data, primarily high altitude aircraft data, in a variety of tasks specified by the Maryland Department of State Planning. Results of this evaluation, presented in detail in the text of this report, have led to different uses of different sensors, depending on the value of each as a source of planning information based on information content, cost-effectiveness, reliability, and credibility. Also included was an analysis of the key techniques and procedures for implementing remote sensors, particularly ERTS, in a statewide planning program. This discussion consists of a summary of those results.

Utility of ERTS Data as a Source of Planning Information

The utility of ERTS-1 data was evaluated on the basis of its applicability in a variety of tasks typical of a contemporary land use planning program at the state level. Major factors in the type of results obtained were the uniquenesses of Maryland, specifically its size, detailed physical and cultural landscape, and the wealth of collateral information already existing. The general effect of these factors was to create a demand for fine rather than coarse-grained information. Results are summarized on the basis of two capabilities ERTS data contains: (1) an ability to substitute for traditional sources of information and to derive the benefits of displacing ineffective data collection systems; and (2) an ability to gain new or unconventional information and derive unexpected benefits.

ERTS Substituting as a Data Source: ERTS has demonstrated capability as a substitute for other data sources in deriving certain types of land use information, examining ephemeral or dynamic phenomena, and providing means of updating collections of static data. Results of this project indicate that the uniqueness of Maryland as a test site limited the degree to which these capabilities could be demonstrated.

A satellite system has a greater applicability for providing earth resources information to larger planning jurisdictions than to small ones. As a general rule, states are more likely to use the data than counties, and counties are more likely to use the data than cities. The same rule applies to combinations of jurisdictions: multi-state planning, regional or council of government-type planning, and planning for special districts. Furthermore, a satellite system has greater applicability for those jurisdictions which have a mandate to do regional types of planning and have administrative programs that require a continuous supply of earth resources information (e.g., environmental impact statement reviews). A state planning agency is perhaps the most probable user of relatively coarse satellite-based remote sensing information and the best example for this type of study.

° Land Use Inventories:

ERTS Land Use Inventory: ERTS imagery has been employed in land use mapping and updating maps both at Statewide and regional levels. Specific attention was directed toward extracting Level 1 land use information for one point in time - January, 1973 (Figure 4, Chapter IV, page 51). January was used primarily because it was the only time the entire State was imaged essentially cloud free at the time of the analysis. While these data were adequate as a basis for interpretation, data from other dates would have considerable additive value. Subsequent efforts were directed towards demonstrating the capability of extracting more detailed information from the satellite imagery. These studies were conducted primarily to determine the utility of ERTS-1 data for preparing and updating land use maps based on the land use classification system adopted by Maryland.

ERTS data has a demonstrated capability to produce Level I land use information (U.S.G.S. classification) at a cost substantially lower than the cost to produce similar information by traditional means, e.g., aggregating detailed information to more general categories. Professional judgment determined that ERTS capabilities to generate land use information at Levels II and III presently could not meet the demands of the State General Plan project, particularly the demands of local jurisdictions to which the State supplies data. Therefore, additional funding was provided by the State to modify the land use phase of the project by collecting Levels II and III data with high altitude aircraft imagery. Land use classes in the U.S.G.S. system were also modified to better conform to State and local agency requirements. The immediate relevance of ERTS data was a factor continually affecting judgments by the Principal Investigators that determined where and to what degree ERTS data would be applied.

The ERTS-derived land use maps and mosaics have had other uses, most of which are unique and difficult, if not impossible, to equal with high altitude data sources. The techniques and products provided State planners and other users with a cost-effective "quick look" at growth patterns and land use changes at the regional and statewide scales. By this means, ERTS data illustrated the need for planning, particularly in the more dynamic areas, e.g., the Baltimore-Washington corridor. Furthermore, the preparation of ERTS land use maps expedited some of the more specialized studies which were carried out later in the project; specifically, the analysis of the ERTS-1 digital tapes and the design of th State's geobase information system.

- <u>Studies of Critical Areas</u>

Studies of critical areas in Maryland required several types of capability from remote sensing: capability to detect significant changes periodically and in a timely manner; capability to perform this task at statewide as well as local scales; and, capability to obtain unique information at a regional scale. Professional judgment was used to determine how sensors would be applied to the various tasks.

Many details in urban and suburban landscapes such as small parcels of a discrete land use class and the characteristics of residential land uses which create sub-classes are too fine to be observed on ERTS images. More noticeable, however, are changes which occur in the natural landscape seasonally and, in the urban landscape, with growth and development. Having this capability, ERTS data can be used to define areas where detailed information must be obtained to update existing maps.

Ability to detect significant land use changes at the local level was important in studies involving types of marinas and recreational developments of lake and oceanic shorelines. High altitude aircraft imagery was chosen as a data source because it provided the detail the planners needed to regulate activity. ERTS-1 data was determined unsuitable for this purpose because of the coarseness of the data provided.

Land use change detection was also attempted in surburban and urban areas primarily to determine the need to update land use maps at Level II detail. High altitude aircraft imagery was chosen for this purpose mainly because it was determined better able than ERTS to serve the information needs of the planning community to simultaneously determine both land use change and Level III land use information accurately and reliably. Results indicated that both land use changes and additional detail could be detected and obtained. ERTS capability in this area was determined to consist only of change detection such as to justify occasional detailed analysis to update maps, which is unrelated to compiling a total survey at the detailed level.

ERTS capabilities in the area of detecting and monitoring bare ground were demonstrated provisionally, with the recommendation that additional research be conducted to develop the procedure operationally. Emphasis placed on rapidly inventorying and analyzing bare ground by the planning community led to a series of experiments using automated digital and photographic means of analysis. Results indicated a high degree of ability to detect bare ground, 75-80% accuracy could be obtained through digital analysis of multispectral data, but with a high commission error (150-250%) caused by concrete and roof tops. Since this information is important for planners to regulate the land development process, commission errors can be tolerated as long as identification accuracy remains high.

ERTS-1 was the primary remote sensor used in determining the general applications to forestry and forest defoliation. ERTS has a definite advantage as a data source in forestry since it can provide the same general categories and boundaries of forest types as obtained from high altitude photography in almost half the time. The State has a continuing interest in these data for effective environmental and general comprehensive land use planning.

The ability to detect forest defoliation, however, depends on its intensity. Heavy defoliation can be identified, but lesser intensities are recognized only when adjacent to heavy defoliation. Users of this information need to have defoliation levels defined, measured, and to have the distribution evaluated within 24-48 hours of imaging to employ suppression measures. Timing of the overpass and the receipt of data thus are critical in applying ERTS-1 data to forest defoliation. Improved resolution, greater frequency of coverage, and rapid delivery of the data are all required to make satellite imagery operational in this application.

Identifying geologic lineaments and areas where sand and gravel are extracted was effectively demonstrated from ERTS-1 imagery. Such information contributes to the General Land Use Plan in several ways: it identifies locations of major faults and fractures for general route planning and the siting of structures (e.g., nuclear power plants); it identifies areas of mineral development so that planners may monitor the extraction process and the rate of recovery, thereby assuring that environmental safeguards are protected and that undeveloped sites are protected for future use. The importance of ERTS-1 imagery in siting is underscored by the Atomic Energy Commission which requires an ERTS-1 based lineament map as a part of the application for nuclear power plant construction.

Use of ERTS-1 data in a water resources application effectively demonstrated to land use planners the relationship between land use (economic activity on the land) and land cover vegetation (soils) as broad area sources of pollution that affect water quality. In a water resources application, however, such as to identify specific point sources, ERTS-1 has severe limitations due to resolution as well as timing of the overpass and delivery of data in an operational monitoring program. The impact of the above demonstration is felt most in the development of land use policy guidelines and their evaluation of the tradeoff between land use regulation and water quality.

- <u>Land Capability/Suitability Analysis</u>

Capability/Suitability analysis is the basic technical and analytical task that supports decisions on how land will be recommended for use. It is the result of integrating physical, social, economic, and institutional criteria for evaluating the potential uses of the land. Because of this integration and because of the need to use weightings that express the relative importance of each criterion, and because of the rising importance of all criteria used in this type of analysis, planners have come to rely more on automated methods of analysis rather than purely intellectual methods of generalization.

Recognizing both the importance of this analysis to a statewide General Land Use Plan and the current methods of performing this type of analysis, the State of Maryland initiated development of the Maryland Automated Geographic Information System (MAGI). Designed to serve the widest variety of users, construction of the system favored raw data at high levels of detail derived from a variety of sources. Data formats were required that were compatible with the types of information existing within the user community, which was extremely varied and extended to local community levels where information generally was highly detailed. In other words, by design, the system was made compatible with the needs of both the State planning program and local users who rely on the State for information. The role of ERTS-1 in such a system is less as a source of primary data for constructing the system but more as a source of information for maintaining it. ERTS-1 data has the potential to indicate when updating the information bank is necessary and for determining the priorities of various kinds of updating. Capabilities of ERTS-1 in this capacity could not be comprehensively evaluated within the time frame of this study. Evaluation was, however, recommended to be conducted in an ERTS-B proposal that would extend this experiment.

ERTS-1 as a New Data Source: Within this experiment, several capabilities were demonstrated that fall into the category of new or unconventional data from which unexpected benefits could be derived. The most important of these is the role of ERTS-1 as a communication device and catalyst and vehicle for organizing thought processes concerned with environmental management and land use policy. Other new capabilities were strongly implied, such as targeting for detailed information collection and "quick look" analyses to determine the need for updating information banks, which could not be fully examined within the time frame of this experiment. The complexity of the Maryland physical environment contained within its small size, and the breadth and depth of the information pool available to the planning community precluded the analysis of ERTS-1 as a standardizing tool or base line of reference, or as a tool that was flexible and compatible with existing data. Spatial and spectral resolution were limiting factors in applying the data to forestry defoliation and water resource applications; in addition, these are applications which often require coverage more frequently than every 18 days.

° Capability as a Catalyst and a Communication Device

Chief among the difficulties in technology transfer is the matter of developing the credibility that the new technology is comparable with the old and that it has additional advantages that make its adoption worthwhile. One of these advantages may be that the new technology provides a better means of solving old problems.

Throughout this experiment, emphasis was placed on technology transfer and communication. Meetings and presentations were held on numerous occasions by the Principal Investigators with a wide range of State officials, county and local officials and planners, as well as private interests. The Governor of Maryland, the Honorable Marvin Mandel, advocated the use of ERTS-1 data in evaluating statewide resources in conferences among governors of various states. The results indicate ERTS imagery is an effective communication device that can cultivate interest in land use planning, land management, resource conservation, and interest in the aesthetic value of physical and cultural landscapes. ERTS images give a synoptic statewide perspective to resources, opportunities and areas of concern.

ERTS images generate an inquisitive interest which results in an increased demand and acceptance of future satellite systems. One of the more effective uses of ERTS-1 in this project was the development of a mosaic of images of the State of Maryland. Simple overlays were prepared to accompany this mosaic containing political boundaries and geographic features to orient users. Fault and fracture patterns were also presented as overlays to the ERTS mosaic. Geologic, soil, and land use maps were effective tools in orienting all levels of planning as well as planning "publics" to the comprehensiveness of the physical environment and the interrelatedness between it and land usage, public safety, and environmental quality.

° <u>Capabilities as a Targeting and "Quick Look" Device</u>

ERTS-1 data may be applied to identifying areas of land use change and identify areas of potential need for updating existing land use data. Cost-saving advantages have been demonstrated for such applications of ERTS-1 data among states whose interest and concern for planning problems require immediate response with new data and who have extensive programs of information collection. Capabilities of ERTS-1 data as a targeting and "quick-look" device are best applied to defining the extent of planning problems of unknown dimensions, and to determining the need for, as well as updating of, information systems once they have existed for some time. In both instances, ERTS capability could not be fully evaluated in the Maryland experiment: (1) because the critical planning problems had already been defined; and (2) because the information system was in the process of development. Evaluations of these types were recommended, however, in the ERTS-B proposal related to planning applications of satellite data in Maryland submitted by the two Principal Investigators of this experiment.

° <u>Capability as a Standardizing and Flexible Tool of Analysis</u>

The potential for standardizing data collection and reporting techniques by referencing all planning data to ERTS was not fully evaluated within this experiment. The level of detail in the data was determined by the data needs of the statewide General Land Use Plan program on the one hand, and the State's responsibility to meet the data needs of the lower jurisdictional planning agencies on the other. Demand for detailed information as in Maryland is most likely the result of the high quality of existing information and the intricate pattern of human and physical landscapes of a small state which can only be described by detailed classifications.

° <u>Capability to Offer Information That is Timely</u>

Although use of the data once imaged can be expedited, present design specifications of the ERTS system preclude the more frequent coverage that is required for enforcing regulations or initiating suppression programs which must respond immediately to the earliest stages of a problem's development. The trials using ERTS data in this experiment focusing on forest defoliation and water resources require a higher degree of timeliness than the trial that was to identify bare ground, where inventorying every 18 days is an acceptable procedure. In other words, present system performance characteristics with respect to timeliness are geared to certain classes of dynamic phenomena. The most serious limitations in the forestry and water resource applications, however, were the optical and spectral resolutions of the system and their ability to generate information that was useful directly for that purpose (e.g., sub-classes of forest defoliation; variations in water quality; point sources of water quality degradation).

RECOMMENDATIONS

Several recommendations can be made to improve the procedures and techniques of analysis using ERTS data, especially the problems of technology transfer and technological development necessary to create a more effective use of this sensor. Further recommendations are made that relate to the methods and results of this project.

Technology Transfer: Transfer of new technology requires a means of training potential users in operational analytical techniques at low cost. Generally, training is not available to users who are not experimenters or affiliated with experimenters. Further use of the data is likely if potential users are shown methods that apply in particular situations rather than general situations, i.e. in an applied rather than theoretical context.

- Remembering that public planning agencies generally do not have funds to conduct research, it is recommended that in order to increase the likelihood of adoption, the capabilities of sensors should be developed before they are exposed to the community of potential ERTS data users. Adoption can be facilitated if the technological community understands the needs of the user community, the nature of the data they use, its purpose and justification. Therefore, it is recommended that experimenters ally themselves with users and prepare objectives that directly relate to practical problems.

Technology Development: The present as well as other NASA-ERTS-1 experiments surveyed by the Principal Investigators point to the need to continue certain lines of research and further investigate applications of the data before final judgments are rendered on the value of the system. Toward that end, proposals have been prepared for continued research under ERTS-B funding that extend the results of ERTS-1 experiments. This experiment is no exception; specific recommendations are made in the following paragraphs that would extend the present research as well as other aspects of the research program. General recommendations are also made related to the performance of the total system. These recommendations will conclude this section of the report.

° System Performance Recommendations

Limitations of the present performance characteristics identified throughout all ERTS-1 experiments related to each disciplinary area should be collected and evaluated as an aid in defining the characteristics to incorporate in future satellite systems. Limitations identified in this experiment focus primarily on resolution and frequency of coverage. As input to future system performance specifications, it is therefore recommended that an optical resolution of Skylab 190-B (color) photography - + 15 meters - if needs for information similar to Maryland will be met (which are not altogether typical of the entire community of state planning agencies). Narrower spectral bands in the .7 - .9 μm range would also help separate forestry species.

In those applications where timeliness is important, e.g., forest defoliation and water quality, frequency of coverage cannot be determined precisely due to the variation in the ephemerality and persistence of each phenomenon observed; whereas, more frequent coverage (e.g., every nine days) may provide information useful in suppressing forest defoliation, water quality observations must be made virtually instantaneously if control is to be implemented, i.e., immediately after discharges, rains, etc. In the latter instance, demands for information are greater than an imaging satellite system can supply. Therefore it is recommended that frequency of coverage requirements for an operational satellite in land use applications be based on serious consideration of the range of coverage requirements for the types of dynamic problems faced by planners.

The capability of the system as a water resources information satellite requires evaluation on the basis of different criteria. Whereas, demonstration of water quality degradation can be effective in showing the need for land use planning, actual water quality measurement should be performed by other elements of the ERTS-1 system such as the interrogating data collection system (DCS), or, by other sensors evaluating ambient conditions and reporting on a real-time basis, including unpredicted conditions. As an imaging system, improved optical resolution would help identify point sources on a regional basis and improved spectral resolution would help separate levels of water quality and better identify the nature of the water quality degradant.

- Project Performance Requirements

Many of the previous system performance requirements would substantially improve the results of this project and greatly increase the likelihood of developing operational uses of ERTS data. Within the present project, however, are several areas of potential use of ERTS-1 data which require further research to become operational.

The first of these areas is the experiment to detect bare ground with automated techniques. Results of this experiment suggest that further refinement of the procedure might provide a monitoring capability that would achieve operational status as an early warning system used by land use planners to protect critical areas and sensitive environments. Therefore, it is recommended that additional refinement be concentrated on the spectral training sets and identification algorithms and the results applied to the proper ground truth and satellite imagery data.

Another area where benefit could be obtained by extending the experiment is to utilize ERTS-1 mosaics and imagery as a method of presenting alternative plans and planning concepts, thereby connecting plans and concepts to a spatial setting where more realistic evaluation can be made. It is thus recommended that plan presentations use this imagery after the ERTS experiment has ended and as long as it is required by the planning program. It is further recommended that the imagery be used continually in the State's planning programs as a means of examining areas outside Maryland where the State lacks data, to test the conformance of plans and policies with other jurisdictions.

During the performance of this project, NASA/Wallops responded in a timely fashion to obtain low altitude aerial photography over several specific areas of particular interest of the State Planning Department/Principal Investigator. These data were additional to high altitude aerial photography acquired by NASA seasonally between Spring, 1972 and Fall, 1973. Due to the low resolution of ERTS data, seasonal high altitude aerial photography has continuing applications to a broad range of state and regional programs, and among numerous cooperating agencies and other public and private users.

Whereas timeliness is one criterion for repetition, cloud cover is another that relates directly to Maryland and bears directly on the usefulness of information actually obtained. In addition, situations that derive benefits from timely special request low altitude photography, as well as routinely acquired high altitude aerial photography, continue to arise at accelerating rates of interest and application. It is therefore recommended that both high altitude seasonal aircraft coverage and timely special request low altitude coverage be continued by NASA. It is further recommended that these services be made available to both ERTS experimenters and non-experimenters which constitute a large and growing user community. The most appropriate high altitude sensors are high resolution metric mapping cameras (e.g. RC-10 or equivalent) with color infrared film, acquiring contact image scales of 1:120,000 and 1:60,000.

CHAPTER II

PROJECT BACKGROUND

The project history is complex; two projects are actually operating simultaneously. The first is the statewide land use planning project in Maryland; it has the longest background, the most extensive involvement, and the highest priority. The second project is the National Aeronautics and Space Administration ERTS-1 experiment, "Applications of ERTS-1 Data to Integrated State Planning in the State of Maryland," which functions within the first project as one of its information sources. The experimental nature of the latter project comes from the fact that a test was made of the utility of ERTS data within an operational planning program. The data may be developed, enhanced, and manipulated only insofar as it provides information useful to the General Plan and does not detract from its pursuit.

This unique project-within-a-project cannot be reported without discussing the objectives for planning prior to discussing the role of ERTS-1 data in meeting that objective. The following sections elaborate upon the background and the principals involved in both projects. It is followed by a description of the objectives for measuring performance in the experimental phase and the steps in the overall procedure.

HISTORY OF THE PROJECT

The experimental project developed as a result of the fortuitous and timely introduction of the Maryland Department of State Planning to remote sensing technology made by one of the project investigators, Earth Satellite Corporation, in 1971. The result was a joint proposal to develop applications of ERTS-1 data that are related to an operational planning program. In this way the project is less experimental and more operational in nature. The ability of ERTS data to substitute for conventional data is determined in a competitive situation. Results of this competition document the present value of ERTS-1 data to state planners, and help identify system performance requirements for the future.

Development of the State Land Use Plan: The legislation creating the Maryland Department of State Planning (Articles 41 and 88C, Annotated Code of Maryland) assigns to the Department the responsibility for preparing and updating "a plan or plans for the development of the State, which plan or plans collectively shall be known as the State

Development Plan." The State Development Plan is a guide for State development and expresses the conditions ultimately desired in the State. It describes desirable general development patterns and related facilities and services, as well as the management of the State's natural resources.

The Maryland Department of State Planning in cooperation with other State, regional, and local agencies will prepare by December, 1975, a Generalized Land Use Plan for the State which will include:

(1) recommendations for the most desirable general pattern of land use within the State;

(2) recommendations for the major transportation facilities and services within the State;

(3) recommendations for the major public facilities and services;

(4) a statement of goals, policies, standards and criteria upon which the Plan is based; and

(5) recommendations for actions to implement the Plan.

NASA-ERTS-1 Program: The National Aeronautics and Space Administration has sponsored research in broad applications of remote sensing in various terrestrial problem areas. A major effort in the conceptualization and analysis of remote sensing research and practical applications was undertaken by the National Academy of Sciences in 1966-68. A series of topics with potential applications were identified that could be studied through remote sensors. The topics which were appropriate to state land use planners were:

(1) Forestry-Agriculture-Geography (including urban and regional planning);

(2) Geology; and

(3) Oceanography and Hydrology.

Many of these topics either related directly or indirectly to Maryland's Statewide land use program, in process. A current Federal program, the National Aeronautics and Space Administration Earth Resources Program, made funds available to examine the applications of satellite remote sensors to practical problems. The Earth Resources Program and the Statewide Plan program were an obvious opportunity and a setting for a practical test.

Relationships between Investigators: In cooperation with the Department of State Planning, Earth Satellite Corporation conducted a series of three meetings with Maryland State officials, in 1971. The purpose of these meetings was: (1) to briefly introduce the participants to remote sensing technology; (2) to explain the status of current Federal programs including the National Aeronautics and Space Administration (NASA) Earth Resources Program; (3) to discuss and illustrate applications of the technology to problems faced by State administrators; and (4) to discuss with the various department representatives specific State problems and the possible long and short range applications of remote sensing technology to the solving of these problems. It should be noted at the outset that Earth Satellite Corporation's objectives are to apply existing technology in operational programs. Thus these meetings were concerned with what is possible at the present rather than experimental applications. The meetings were concerned with environmental quality, open spaces, natural resources and geology, and transportation and urban planning.

Remote sensing was becoming a major, rapidly expanding source of basic data for planning, analysis, and decision-making purposes. The use of such data had become clear to Departments in Maryland. The standardized use of remote sensing and associated data can contribute to the always difficult task of obtaining imaginative and coordinated planning throughout the State Government.

With the aid of a consultant to the Department of State Planning, Mr. Hal Wise, a presentation was also made before the Governor of Maryland, The Honorable Marvin Mandel. The result of this meeting was an encouragement of the Department of State Planning's participation in the NASA Earth Resources Program. The funding of the joint Department of State Planning-Earth Satellite Corporation's proposal, "Applications of ERTS-1 Data to Integrated State Planning in the State of Maryland," made that participation a reality.

Involvement of Other Agencies: The formulation of as comprehensive a project as a statewide General Plan is a time-consuming and expensive task which draws on all allied or line agencies of the planning department. Many of the individual tasks in a planning program are often dealt with by agencies with specialized interests concerned with greater breadth or depth of analysis than the plan itself provides. These can be agencies within the State hierarchy as well as outside. The Maryland State planning program has drawn on several of these sources. For example, the development of a statewide detailed land use map for 1973 was not necessary for the purposes of the Plan itself, but was developed mainly to satisfy the needs of county and local planning agencies. In this instance, additional funding was obtained from the State itself. NASA funding accounts for only one small share of the work described in this report. Sources of funding include:

(1) State of Maryland

(2) United States Department of Housing and Urban Development (701 grants)

(3) United States Economic Development Administration

(4) Hurricane Agnes Flood Disaster Coordination

(5) Appalachian Regional Commission.

SCOPE OF THE PROJECT

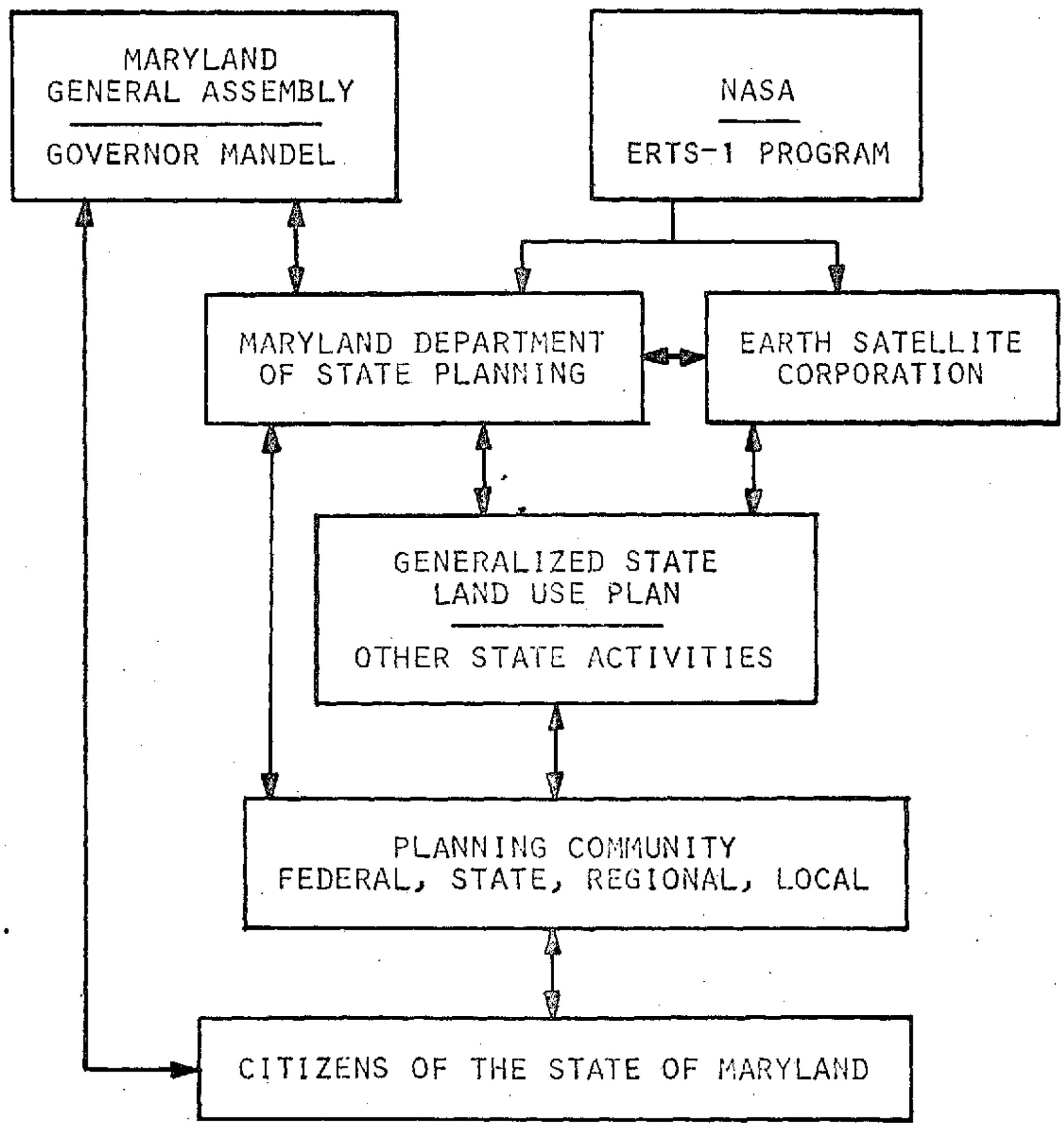
The Department of State Planning is responding to its legislative mandate to prepare a State Development Plan by developing a Generalized State Land Use Plan. The National Aeronautics and Space Administration, for separate reasons, has supported a research program that explores the applications of the Earth Resources Technology Satellite (ERTS-1) to practical problems. The State Land Use Plan program of the State of Maryland was thus utilized as a vehicle for testing the applicability of these and other remotely sensed data, and became a key to determining the applications and users in a "realistic setting." The potential significance of the Land Use Plan to Maryland, and the realization that pending Federal legislation will encourage if not require each State in the Union to develop such a planning process within a short time, made the experiment an ideal vehicle for testing the applicability of remotely sensed data and evaluating its effectiveness: (1) as a substitute for traditional data, where comparisons of cost, information content, ease of access and use, adaptability, and quality were evaluated; and (2) as a new means with new capabilities that can provide a better mode of planning.

The internal organization of the Department was structured to permit widespread diffusion of data and techniques to a broad user community. Furthermore, the network within the Department and between it and other planning agencies was used to feedback the impressions and judgments of the user community. This response provided the investigators with an opportunity to adjust, modify, or otherwise alter the initial technique or output data in manners that mitigated problems discovered in each stage of the investigation.

Perhaps the most significant element of the experiment was its capability of motivating the diffusion of space technology to a diverse planning community, and its measurement of both the success of techniques under development as well as the degree of acceptance or reliance on the data source. The ability of the Department to diffuse techniques and results through a user community forms a line of continuity throughout the project (Figure 1).

FIGURE 1

OPERATIONAL ERTS DATA DIFFUSION
STATE OF MARYLAND



Objectives: The purpose of the project was one of demonstrating that aircraft and satellite remote sensing can make a significant contribution to:

(1) assessing the physical, economic, and social resources of the State of Maryland;

(2) formulating cogent development and growth policies;

(3) monitoring resultant development trends; and

(4) providing a continuing, dynamic planning information base.

These objectives were basically derived from the demands of the planning program. To make them more specific to the experimental nature of this project, tasks were set to be performed by the Department of State Planning and the contractor, Earth Satellite Corporation, assisting the Department in technical and analytical matters.

Research Design: The tasks carried out by the investigators were designed to be consistent with the approach, intent, and objectives specified in the Planning Agency's proposal to the National Aeronautics and Space Administration. They were also designed to conform to the Study Design for the Maryland Generalized Land Use Plan so that mutual purposes could be served. These tasks consist both of specific and general requirements:

(1) to produce a 1970 land use inventory;

(2) to prepare a capability/suitability analysis of the State's resources;

(3) to develop techniques for future updating and modification of both items above;

(4) to perform a temporal analysis of land use in certain areas of the State, and updated the land use inventory to 1972;

(5) to formulate land related goals and policies based on the results of the project's research;

(6) to review preliminary alternative land use plans on the basis of information developed in the project; and

(7) to evaluate remotely sensed information of several types in the context of the planning program.

Most of the above tasks relate to specific products that can be developed from remotely sensed information, while others relate more to the general problem of integrating a new, unconventional data source in an operational program. Guidelines were established that determine how each task will be pursued to insure meeting the experiment's overall objectives. The guidelines were:

(1) the research must provide material/techniques for operational use;

(2) the research must be linked to applications through institutional and human models;

(3) the research will be diffused through existing or newly created mechanisms to test applicability; and

(4) the research (techniques, methodology, etc.) will have potential application to other state planning agencies, etc.

Later sections of this report will identify the actual experiments/applications that have evolved. Briefly, there are three types: those related to obtaining land use data, critical areas, and land capability/suitability. For each of these experiments/applications, findings are reported in the body of this report.

The research was designed to insure diversity, create the greatest potential for a positive impact in planning, and develop a technique, model, or data, that would be operational on a statewide basis.

Major/Minor Tasks: The major tasks discussed earlier have been divided into sub- or minor tasks. Minor tasks describe the complex nature of each major task and show how they relate to needs of the planning program and to methods of analyzing remotely sensed data.

(1) 1970 Land Use Inventory

Identify sub-areas within Maryland
Adopt Land Use Inventory Scheme
Classification of State Land Use
Refine Existing Inventory
Ground Truth Where Necessary
Land Use Map Product
Quantification by Class

(2) <u>Capability/Suitability Analysis</u>

Identify Capability Classes
Identify Suitability Classes
Critical Areas
Define Guidelines for Capability
Define Guidelines for Suitability
Determine Capability from Imagery/Supplementary Data
Ground Truth Capability
Ground Truth Suitability
Capability Map Products
Suitability Map Products
Quantify Capability Maps
Quantify Suitability Maps

(3) <u>Techniques for Updating Land Information</u>

Land Use Inventory
Capability Classes
Suitability Classes
Determine Short Range Data Storage for Images and Interpretation
Implement the above
Advise on Long Range Information Systems Requirements

(4) <u>Temporal Analysis of Land Use in Selected Areas</u>

Land Use Inventory Update to 1972
Temporal Analysis of Map Products
Land Use Analysis of Map Products
Quantification of 1972 Land Use Inventory Update

(5) <u>Formulate Land Related Goals and Policies</u>

(6) <u>Review of Preliminary Alternative Land Use Plans</u>

(7) <u>Evaluate Remote Sensing Information</u>

Land Use Inventory
Capability Information
Suitability Information
Compare Usefulness of Satellite to Other Imagery
Determine Level of Utility of Satellites for Significant Contribution
Compare Incremental Cost/Savings vs. Common Data Sources

(8) Future Satellite/Aircraft Coverage and Requirements

Future State Activities
Define Sensors, Times, etc.
ERTS-B and other Operational Satellites

Research Phases

The Maryland investigation to apply ERTS-1 and other remotely sensed data to comprehensive State planning was conceived and conducted in three scheduled reporting phases. A series of tasks was performed during each of these phases.

Phase 1, Pre-Launch, included approximately six months of preparatory activities prior to the analysis of any ERTS-1 data. During this period the 1970-72 land use inventory of Maryland was acquired and compiled, and planning and analysis of available materials for other tasks were initiated. During this phase it became apparent that the program's activities and results could readily diffuse through a keenly motivated and interested user group within the Maryland State and regional planning community. This group, however, held understandable reservation and skepticism which required a coordinated approach to technology transfer throughout the investigation.

Use and application of remotely sensed data by State and regional planners occurs at several levels of sophistication and complexity. The simplest and perhaps most common use then, and to an extent still today, is that of large scale black-and-white aerial photography, and enlargements of these photographs. Less common has been the use of small scale color aerial photography. The learning process as it applies to land use planners begins with the first two types of imagery; it then proceeds to developing simple manual color enhancements, more complex analog processing and enhancement, and finally, to highly complex digital enhancement.

Beginning in Phase I and continuing throughout the ERTS-1 demonstration project, a close working relationship evolved with State and regional planners led by the efforts of the Principal Investigator and his staff. It was determined and planned that the ERTS-1 project would evolve from relatively simple procedures and demonstrated applications -- of both high altitude aerial photography (an advanced tool to planners) and ERTS-1 imagery (then an unknown tool to planners) -- and move towards the more sophisticated. In this process of technology diffusion and transfer, planners were not only informed by exposure to the processes, procedures, and potential applications, but also found those areas where data of various sources, forms, and processes can (presently and in the future) be integrated into their operational planning responsibilities.

Phase II, First-Look Analysis, included preliminary evaluations and analysis of ERTS-1 imagery during the first four months of the satellite's operation. Portions of Phase I and Phase II overlapped and were conducted concurrently. Interim progress reports and a Data Analysis Plan were issued during Phase II.

In addition to the First-Look Analysis of ERTS-1 imagery, several studies were initiated which evaluated the applications of high altitude aerial photography to the analysis of land use and "critical" areas designated by State planners. These studies were an integral part of the diffusion of more sophisticated ERTS-1 analyses by users in the planning community. Aircraft support requirements were evaluated and their seasonal continuation recommended.

The coordination of existing ground truth data was also considered during Phases I and II. Considerable quantities of highly useful ground truth data were found in Maryland in the form of various maps, records, statistics, and reports. These materials were used directly in the analysis of ERTS-1 and aircraft imagery for several tasks, particularly in the Land Use Inventory and the Capability/Suitability Analysis. Their format, however, in many separate documents, made full utilization difficult and inefficient. After considering and exploring a variety of solutions to this dilemma and evaluating alternatives, a computer based "Maryland Automated Geographical Information" (MAGI) System was proposed, accepted, and subsequently implemented.

Phase III, Continuing Data Analysis, extended over 18 months during which period a variety of ERTS-1 and aircraft data applications for comprehensive State planning were evaluated and image analysis techniques were investigated. The integrated roles of remotely sensed data in operational State planning were explored, and some applications implemented. During Phase III, work elements were carried out in several tasks concurrently. Image analysis included special studies using ERTS-1 and supporting photography in a variety of "critical areas" designated by the State planners; the evaluation of remote sensing data focused particularly on ERTS-1, but included a variety of image enhancement techniques and digital image analysis procedures.

The Maryland Automated Geographical Information System was implemented, is fully operational, and supports the investigation's capability/suitability analysis. An ERTS-1 color mosaic of Maryland was constructed and distributed to users in the State planning community through project participation by the Governor of Maryland, the Honorable Marvin Mandel; the mosaic also provided a base for statewide investigations (e.g. geologic lineaments) and presentations. Procedures were developed for making data and results more widely available to planning users. Several efforts produced results which led to further operational-status programs under non-NASA funding; for example, analyses for updating and refining land use information led to a separate program for compiling a detailed 1973 land use information for Maryland. The results of this program were subsequently used in further ERTS investigations, such as the analysis of ERTS digital data and the development of preliminary land use plans. During Phase III a variety of Technical Reports and Technical Memoranda were released in addition to several formal presentations and papers.

CHAPTER III

INFORMATION DEMANDS BY STATE LAND USE PLANNERS

During the last five years, the public concern for environmental quality has caused thorough reconsideration of land use planning and management in restructuring our society's relationship to its natural and environmental resources. Incentives were provided for restructuring Federal, State, and local land use planning processes and techniques. Specific laws have been passed and institutions created to deal with the protection of the environment. The State has been the main level where this activity takes place, because it has been the traditional source of police power delegated by the U.S. Constitution. Furthermore, many of the environmental issues can be dealt with successfully only at the State level because: (1) they cross jurisdictional boundaries and are intractable by any individual lower jurisdiction; and (2) they may well have been created by the individual aims and ambitions of those jurisdictions. Consequently, the State has been vested with greater authority to coordinate lower jurisdictions and to reserve a greater share of the police powers unto itself.

The following chapter describes the general responsibility of statewide land use planning, with particular emphasis on the State of Maryland, the site of this experiment. It examines the development of the Maryland statewide land use plan and identifies its objectives. This program was chosen as a setting for a realistic test of the viability of ERTS-1 and other remotely sensed data in meeting the various program objectives.

OVERVIEW OF STATEWIDE LAND USE PLANNING

Until recently, land use management has been exercised primarily by local communities on the basis of state enabling legislation providing for the establishment of city/county zoning. Not all communities exercise this control because the legislation is often not mandatory. The earliest attempt to build up a planning and regulatory function at the state level dates to the late 1920's when the Supreme Court ruled in the landmark Euclid vs. Ambler Realty Company (1926) case that: "states are the legal repository of police power." This decision confirmed that states and, by delegation, municipalities, have the right to regulate land use in a manner that would provide for the health, safety, morals, comfort, convenience, and welfare of the community. The U.S. Department of Commerce subsequently issued a Standard Zoning Enabling Act to provide a model for the states to institutionalize the Euclid decision.

Although zoning laws conceivably could have been used to develop balanced growth patterns, traditionally they have been used to protect residential and urban areas with little regard for the remainder of the land or of the environmental considerations. As Stephen Sussna explains in a research monograph prepared for the Urban Land Institute: "The objectives of zoning were: (1) the protection of property values by requiring uniformity in each district; (2) the exclusion of dangerous and nuisance uses from residential districts; (3) the prevention of the over-exploitation of land and the reduction of building density; and (4) the fostering of public service efficiency." Rather than dealing with the growing destruction of the urban environment, city-dwellers followed the path of least resistance and simply moved away from the sources of environmental problems. They postponed the impending confrontation with the problems of urban pollution and mismanaged land use, only to create additional environmental problems in the new areas of settlement.

It is obvious, then, that land management responsibilities, where they have existed, have been largely in the hands of local authorities. Although zoning issues have been debated in the courts and by the public since the beginning of the twentieth century, it was not until 1961 in Hawaii that, on the basis of the Euclid decision, a comprehensive statewide zoning plan to be administered by a state itself was established. In a precedent setting move, Hawaii divided its land into three classifications: agricultural, conservation, and urban. The plan called for State and local cooperation in the administration of the zoning program, while policy for development was to be determined at the State level. Hawaii's decision was based on a growing awareness of the need for statewide coordination of land use as it relates to development opportunities and resource preservation, and was followed by land use management programs in Vermont, Maine, Massachusetts, and, most recently, Florida.

LAND USE PLANNING PROGRAMS OF THE DEPARTMENT OF STATE PLANNING (DSP), STATE OF MARYLAND

The State of Maryland has recognized the need for coordinated comprehensive planning at the State level for many years. In 1933, the State Planning Commission was established by the Maryland Legislature, providing a model other states might use to establish such boards. By 1958, a specially prepared Report on the Maryland State Planning Commission stated that the Commission had assumed national leadership in capital improvement programming and budgeting. It also acted as a consultant to city planning agencies and conducted research and planning in the area of medical care. In 1959, the State Planning Commission was succeeded by the State Planning Department; this change partially reflects population increases and economic development in Maryland and the growing need for expanded planning functions at the statewide level. Article 88C, laws of 1959, provides the enabling legislation for the Department of State Planning:

> "there shall be a Department of State Planning . . . whose purpose is to function as the Governor's staff agency in planning matters . . . . and to prepare, recommend, and keep up to date a balanced integrated program for the development and effective employment of the natural and other resources of the State in order to promote the health, safety, and general welfare of its citizens."

Legislative Responsibility: A series of administrative reforms beginning in 1969 led to the reorganization of the State Planning Department into the Maryland Department of State Planning (stated in Chapter 155, Acts of 1969 and amended by Chapter 596, Acts of 1971). According to Article 88C, the major responsibilities of the Department of State Planning are: "harmonizing planning activities with the planning activities of departments, agencies or instrumentalities of State or local government; rendering necessary planning assistance; stimulating public interest and participation in the development of the State; coordinating plans and programs of all State departments, agencies, and instrumentalities; and coordinating the State programs with the Federal government."

By way of executing these responsibilities, the Department is mandated to undertake the following activities:

(1) Prepare a State development plan, based on studies of physical, social, economic, and governmental conditions, to include: a statement of objectives, standards and principles; recommendations for the most desirable general pattern of land use; identification and designation of areas of critical State concern; recommendations for the major circulation pattern for the State; recommendations concerning the need for and proposed general location of major public and

private works and facilities; a comprehensive analysis and evaluation of the capital plans and programs of the State departments; review and analysis of Federal and State grants, loans or services; other recommendations concerning current and impending problems which affect the State.

(2) Make studies and investigations of the resources of the State and of existing and emerging problems affecting the development of the State.

(3) Undertake special studies and investigations and render advice to the Governor at his request; provide information to the General Assembly and its committees.

(4) Prepare the State's capital program and annual capital budget.

(5) Prepare and revise an inventory of facilities and natural resources.

(6) Cooperate with and provide technical assistance to local, State, and Federal governments and agencies.

(7) Provide information to governmental officials, agencies, and the public at large to foster awareness and understanding of the function of State, regional, and local planning.

(8) Accept and receive funds from Federal, State, local and private sources.

(9) Cooperate with Federal and State agencies in planning for civil defense.

(10) Correlate data concerning publicly owned real property within the State.

(11) Coordinate plans and programs of State agencies to avoid duplication and conflicts; coordinate plans and programs of Federal, State and local governments.

(12) Establish statewide classification standards for geographically referencing basic planning data.

(13) Create a central depository for all general, area, and functional plans prepared by State, regional, local, municipal, and interstate agencies.

(14) Intervene in administrative, judicial, or other proceedings concerning land use, development, or construction which is of substantial State or regional interest.

Structure: Organizationally, the Department of State Planning functions with six divisions: Secretary's Office, Comprehensive State Planning, Regional and Local Planning, Capital Improvements, Research, and State Clearinghouse.

The Comprehensive State Planning Division consists of specialists in transportation, water and sewer facilities, solid waste disposal, land use, recreation, historic areas, land use, natural resources, health, education, criminal justice, housing, among others who coordinate and review all planning activities at the Federal, State, and local levels, and who are primarily responsible for the preparation of the State Development Plan and its components, the Generalized State Land Use Plan and Human Services Planning and Coordination Project.

The Division of Regional and Local Planning consists of six regional offices which provide technical and planning assistance in plan preparation and regional and local planning to all substate jurisdictions. It also acts as a coordinator and liaison with all regional and local planning groups.

The Capital Improvements Division handles all requests for construction of State-owned facilities, and makes Capital Budget recommendations to the Governor, Senate Finance Committee and the House Appropriations Committee.

The Research Division provides comprehensive analyses and information to assist State and local public agencies in carrying out their assigned responsibilities more effectively. Accordingly, they prepare basic socioeconomic information relating to the State and its political subdivisions, analytical reports and studies, and models that identify and evaluate development issues, and information on specific technical matters as requested by the Executive Department, the Legislature, and other State agencies.

The State Clearinghouse is responsible for coordinating reviews of all Federal development projects in Maryland, Federal grants-in-aid projects under the Project Notification and Review System, and the review of all State Plans that the Federal Office of Management and Budget Circular A-95 specifies. The Clearinghouse also serves as the coordinator of Federal and State environmental impact statements, as a repository for the inventory of all public land in Maryland, all transactions involving excess State-owned land and surplus Federal land, and as the point of contact for Federal Regional Council III.

RATIONAL AND PREPARATION OF THE STATE LAND USE PLAN

In 1927, the State of Maryland delegated to local governments the power of enacting land use controls through zoning regulations. The Maryland-National Capital Park and Planning Commission, a bi-county planning and zoning agency established in 1927 to serve Montgomery and Prince George's Counties, is the oldest such agency in the State. Generally, however, city governments with greater population densities, were the first to organize the dual functions of planning and zoning by establishing Planning Commissions and Zoning Boards. To date, all 41 municipalities in the State with a population greater than 2,500 have adopted master plans and zoning regulations.

Planning was extended to unincorporated areas in the recent explosive growth of the past 25 years. All twenty-three Maryland counties and the City of Baltimore have established planning programs, although only four were in existence prior to 1950. Within the past ten years, twenty-one counties have adopted comprehensive plans or substantial parts of such plans.

The pressures of growth and development made it increasingly clear that the State's 1927 zoning enabling legislation was insufficient to cope with the problems facing local governments. Zoning regulations frequently conflicted from county to county; planning and zoning were rarely coordinated; standards for the reclassification of land were confusing; and zoning regulations, designed to guide development on a lot-by-lot basis, had not kept pace with new multi-purpose modes of land development and growth rates.

In the case of the State of Maryland, growth has not been a simple rural to urban redistribution of the State's population, such as other states experienced. On the contrary, rural-to-urban, urban-to-suburban and a general increase in total population took place, all in massive proportions. From 1960 to 1970, the State's population rose by 26.5 percent, from approximately 3.1 million persons to close to 4 million. In 1960, the population per square mile was 314 persons; by 1970, these were 396.6 persons per square mile (about 1-1/2 football fields per person), nearly seven times greater than the population density of the United States as a whole. It is important to note that the rate of growth in metropolitan areas of the State, particularly those counties surrounding Baltimore and Washington, have absorbed most of this growth and will continue to do so.

A number of difficulties have risen from this explosive growth. First of all, increasing demands have been placed upon public services, resulting in an inadequate supply of these services and severe fiscal problems at the State and local levels of government because of attempts to keep pace with the demand. This situation is compounded by the fact that the leapfrog pattern of metropolitan development is frequently the least efficient, most expensive type of development to serve. A further difficulty is the concern that growth is seriously degrading the environment, and consequently, lowering the quality of life.

Purpose of the Plan: The role of the Department of State Planning has increased proportionate to the increasing attention of the State to these problems. In response to its legislative charge the Department has, in recent years, prepared plans, studies, and reports related to such concerns as wetlands, natural features, open space and recreation, and historic preservation. Comprehensive plans have been prepared for dozens of communities; assistance has been provided in the preparation of the Power Plant Siting Program; and comprehensive studies of the Patuxent River Watershed and Assateague Island have been developed and presented as models for other fragile areas. Employment, population, migration, and various other socioeconomic data related to the problem of explosive growth have been provided for planning purposes to all of the State agencies and substate jurisdictions.

The preparation of a Maryland Generalized Land Use Plan is one of the major projects in which the Department of State Planning is currently involved. The increasingly complex problems and responsibilities facing Maryland offer compelling reasons for expediting such a plan.

Maryland's Generalized Land Use Plan (MGLUP) is based on four major premises: first, the Generalized Land Use Plan and planning process can clearly identify, interrelate and establish an effective basis for solving land use and related problems in the State; second, the plan and the planning process can strengthen and maintain intergovernmental cooperation, coordination, and management in the conservation of Maryland's land resources; third, the Plan can provide for the conservation and optimization of State expenditures by guiding land development in an orderly fashion and by promoting sound public investment patterns; and fourth, the Plan and planning process can, by the above means, have a substantial impact upon the future quality of life and growth in the State.

Agencies Involved: The participants in the planning effort were not restricted to the Department of State Planning's staff. Technical assistance has been sought from Federal agencies such as the Department of Interior, the U.S. Geological Survey, the Department of Agriculture's Soil Conservation Service, and other State agencies including the Departments of Transportation, Natural Resources, and Health and Mental Hygiene, as well as local and regional planning agencies.

The Department of State Planning's responsibilities place it in a unique position of providing technical and coordinative assistance in both the horizontal and vertical relationships of State planning.

Similarly, these same channels were available for testing the application of ERTS-1 and other remotely sensed imagery on a variety of subjects with a wide range of potential users.

Information Demands: Many types of information are used in a comprehensive planning program. A general overview can be obtained by examining the four major areas within the planning process which have been emphasized:

(1) An analysis of the consequences of existing State, regional, and local plans and policies which influence land use, as well as the regulatory devices used to implement these existing plans and policies. This analysis will include consideration of the internal consistency of plans within the same governmental unit (water and sewer, recreation), consistency along boundaries of governmental units, and external consistency between vertical levels of government. It shall also consider the impacts of taxation on assessment policies and Federal and State-owned lands, among others;

(2) An analysis of the land use influences posed by supplying utilities, transportation networks, and other public services and facilities and the development of techniques to employ these elements in guiding land use;

(3) The identification of those natural features and processes which establish land use suitability, capability, and environmental sensitivity for various uses; and

(4) Consideration and protection of historical, cultural, ecological, recreational, and aesthetic resources.

Comprehensive land resources data (including land cover/use information of several levels of detail) is basic to a land use planning program. State planners require these data for the entire state to carry out the functions specificed in the first major area of emphasis. The state planning agency's role as a coordinator of local plans requires it to develop a background to use as a reference in evaluating local plans. Consequently, state planners require data of similar breadth as local agencies, but of greater areal scope. The state agency does not generally need as much depth of detail as the local agencies which are more concerned with administering subdivision and zoning codes, a function that necessitates information of parcel-oriented detail.

The second area of emphasis specifies that an understanding of the land development process be manifest in the state's policies of allocating capital works programs and improvements. Frequently, the bases for such policies are poorly founded and only realized *ex post* *facto*. This calls attention to the need for historical studies and monitoring of the growth process, isolating the individual factors which give explanation to particular patterns, and using these data in a process of simulation that will identify alternate policies.

The third and fourth areas of emphasis call attention to the state planner's need for inventories of natural and socio-cultural resources, and for evaluating them with a view of balancing their use with their inherent capability. Physical and social criteria are used to evaluate the resources and rank their various capabilities (primarily by physical criteria) and suitabilities (primarily by social-economic criteria). Carrying out this type of analysis, particularly as it might be done at statewide scope, requires means of assimilating diverse data that relate to each of the state's many areas. Consequently, the requirement for data necessitates not only all the items at the levels of detail required, but means of periodically updating them and revising the information base.

Problems of Data Acquisition: Prior to the advent of automated geobase information systems, use of massive files of earth resources information has been difficult to master and, consequently, serious attention to the capability/ suitability of resources has been largely neglected. Increased attention to these resources has brought about the development of two important technologies which are now being applied: (1) the use of the geobase system, and (2) remote sensing as a source of primary resource information. New capability was realized when the difficulty of coordinating diverse sources of information was resolved by the development of a uniform coordinate referencing system that stores, retrieves, and permits manipulation of several sets of data. Geobase information systems, as these have been called, have been linked to remotely sensed data because of the ease with which several types of data can be extracted from one source and referenced.

CHAPTER IV
CAPABILITIES OF ERTS-1 DATA IN AN INTEGRATED PLANNING PROGRAM

The capability of ERTS-1 data to provide information useful to an operational, comprehensive planning program can be determined when the total product of information from the satellite is compared with the demands of the program. From this comparison, an area of overlap may be determined where the capabilities of the system and the demands of the program merge and an operational use of ERTS-1 data may be defined. The customary procedure in research of this type is to view the satellite as a research vehicle providing data whose use promises great potential but remains to be determined for each application. Typically, one defines the ultimate performance or capabilities of the system before determining the applications of these data. Rarely does an experimental situation provide opportunity to evaluate the performance of the system in a realistic setting.

An operational land use planning program with a comprehensive focus provides a highly realistic setting, particularly when the focus is statewide. An experiment to determine the capabilities of ERTS-1 in this setting provides a highly competitive situation where many types of data are evaluated in terms of their capability to satisfy the demands of the program, cost-effectively. If this competition is documented rigorously and candidly, valuable information can be provided that can help define the nature of operational systems. Important information might consist of why planners use some data and reject others. The scope of research must be rigorously defined: experimental development of ERTS-1 data applications should not detract from other tasks; the quality of ERTS-1 data input to the program should not degrade the quality of the total data content. The focus of this NASA ERTS-1 experiment makes it unique among others: the present capability of the experimental satellite is documented in competition with other systems; data are utilized when they are demonstrated to be credible and cost-effective; procedures are implemented when they are operational or near-operational; and, a method of analysis and reporting is used that provides inputs to the design of operational systems.

This chapter is divided into five sections. The first is an analysis of a set of techniques that describe the general capability of the system. The following section matches these general capabilities with actual problems in the statewide planning program. Subsequent sections of the chapter treat the actual application of these general capabilities and techniques to particular problems.

GENERAL ROLES OF ERTS-1 DATA IN SUPPLYING LAND USE INFORMATION

Viewing surface conditions or land cover is one of the basic capabilities of the ERTS-1 system. Three basic capabilities appear from preliminary use of the data:

(1) initial coverage and mapping of surface conditions in geographic areas not previously mapped;

(2) periodic coverage and update of change in surface conditions previously mapped; and

(3) continuous monitoring of specific changes in surface conditions.

Each capability can be linked with a procedure to acquire information. The following section examines strategies for acquiring information by means of ERTS-1 in combination with other sensors. Distinctions are made throughout the report between the contribution of ERTS-1 as an independent source of data to solving an overall planning problem, and the contribution it makes in a supportive role with other sensors. The scenario of information acquisition logically divides into three parts: independent ERTS, ERTS in multi-staged surveying and sampling, and minor ERTS involvement.

Independent ERTS-1

By definition, this application of ERTS is to users whose demand is for a level of information detail that can be reliably extracted directly from the image or the digital data by manual or automated means and that can be used with little or no collateral data; typically this includes Level I of the U.S.G.S. land use classification system (Bulletin 671). This use of the system lends itself to acquiring data periodically and synoptically for areas without other data coverage, and areas where updating existing data bases and monitoring selected phenomena cannot be done by other means.

ERTS-1 With Multi-Staged Surveying and Sampling

This application of ERTS uses the synoptic and periodic capabilities of the system as a low cost means of effectively deploying higher cost, detailed information collection systems. It can be used in a stratification mode as a means of surveying total areas and identifying and prioritizing regions or areas for various higher levels of detailed analysis. The application can also be in a sampling mode where the system serves as a means for establishing a method of selecting the representative areas for sampling populations of various phenomena. The system typically is used with high altitude, low altitude, and ground survey techniques.

Minor ERTS-1 Involvement

ERTS plays a role in more localized data collection when it operates in a search and detection mode for information which is highly selective or dynamic. ERTS data thus provides an alerting system, an ability to detect changes, and an ability to focus conventional data gathering efforts on areas of change, thereby reducing the costs of conventional data gathering.

GENERAL APPLICABILITY OF ERTS-1 DATA TO LAND USE PLANNING

A satellite system has a greater applicability for providing earth resources information to larger planning jurisdictions than to small ones. As a general rule, states are more likely to use the data than counties, and counties are more likely to use the data than cities. The same rule applies to combinations of jurisdictions: multi-state planning, regional or council of government-type planning, and planning for special districts. Furthermore, a satellite system has greater applicability for those jurisdictions which have a mandate to do regional types of planning and have administrative programs that require a continuous supply of earth resources information (e.g., environmental impact statement reviews). A state planning agency is perhaps the most probable user of relatively coarse satellite-based remote sensing information and the best example for this type of study.

Tasks in the Maryland State Planning Program

State planning agencies have traditionally done a variety of tasks, some specialized and primarily the responsibility of the department, and some which are diffuse and spread among other state departments. Some require the state to collect and use primary data; others require it to collect and dispense data. With this characteristic being common, it is fair to assume that no department operates identically to another; only in the broad outline do planning agencies conform.

A state planning agency is perhaps the best example of the advantages which could be gained by centralizing data collection services, particularly those concerned with earth resources information. A planning agency, being land-oriented, could benefit by being a repository or by having direct access to data on earth resources, socio-economic conditions, land-related public records, etc. Centralization offers the advantages of minimizing redundancies in data collection, and of maximizing the benefits of the data by broadening their use. Centralization conceivably could lead to greater cost-effectiveness through scale economies which in some instances could lead to broader data services.

One means of centralizing earth resources data is through developing one comprehensive collection system, such as the complex of technologies known as remote sensing, including its allied interpretation, analysis, manipulation and storage systems. A remotely sensed image can provide a central vehicle for an information system because it graphically represents the complexity of the physical/cultural landscape; it can become the starting point for detailed analyses. As a representation, it provides a focus for problem-solving in areas which transcend boundaries between traditional fields of knowledge. For example, early in the Maryland statewide planning program it was asked if remote sensing could provide useful information to a series of immediate and long-range problems. Answers were important in determining whether remote sensing would become an important information source in the forthcoming general plan project. Among the questions were those concerned with:

(1) Environmental Quality

- locate sewage treatment outfall points
- map wetlands and evaluate their quality
- provide data to State standards for sewage treatment plants
- assess the damage to vegetation caused by air pollution
- assist in the deployment of air quality sampling stations
- acquire tidal hydrology information
- monitor reservoirs
- establish improved run-off predictions and integrate them in a more efficient waste treatment system
- monitor the extent and effects of accidental discharges in Maryland and neighboring states
- determine the location of airports
- locate thermal sampling sites

(2) Open Spaces, Natural Resources and Geology

- map the Chesapeake Bay and coastal wetlands
- update information on the Chesapeake
- assess water quality
- plan open space

(3) Transportation and Urban Planning

- identify urban land use restrictions
- acquire transportation data

- identify blighted residential areas
- identify major and minor fault patterns

(4) Statewide Planning

- contribute to capital budgeting
- coordinate and evaluate programs under comprehensive State, regional, and local planning
- measure progress and impacts of individual programs
- program alternatives
- advise, guide, and establish policy
- inventory land use
- provide data to determine future land use

Application Areas for Remote Sensing Research

In the formulation of the General Plan program, these problems were consolidated within a series of general tasks and combined with the objectives of the concurrently operating NASA ERTS-1 experiment, and a set of mutually purposeful objectives was formed. The following three sections of this chapter present the results of effort focused on these combined objectives:

(1) ERTS-1 data in land use inventorying;

(2) ERTS-1 data in the analysis of critical areas; and

(3) ERTS-1 data in the evaluation of land capability/suitability.

ERTS-1 DATA IN LAND USE INVENTORIES

Land use information presents many perceptual and conceptual problems which are difficult to resolve; there are many ways to identify and classify types of land use. Most commonly land usage is classified in terms of economic activity (e.g., agriculture, industry, commerce), but intensity of activity (e.g., single and multiple family residences), form, species, and a host of qualitative descriptors have been used to the degree that land use and land cover have been used interchangeably. How a classification is made depends largely on the classifier, his/her purpose, and the perspective. Purposes of the forester differ from the agronomist, from the planner, etc., and the view from the ground differs from that in the air.

ERTS-1 introduces users of land use information to data of a new type and format. New methods typically generate resistance among users, particularly those in the planning community, because of the issue of credibility. Building credibility is a lengthy process involving comparisons of the relative advantages of traditional and unconventional sources of information applied to similar problems. This comparison was anticipated by the U.S.G.S. in the Chesapeake Area Regional Ecological Test Site (CARETS) project which applies remote sensing technology to a variety of earth resource studies with a view of providing a data base for subsequent comparisons with satellites as basic data collectors. The Maryland Department of State Planning borrowed CARETS data, used them in State land use planning, evaluated them, and determined that they would make comparisons by initiating a proposal to test the use of remote sensing data in an operational land use planning program. The land use data base was built in three separate steps:

(1) the 1970 land use inventory

(2) the 1972 addendum to the 1970 inventory

(3) the 1973 detailed land use inventory

1970 Land Use Inventory

The 1970 land use inventory was initiated by the Department of State Planning in cooperation with the U.S. Geological Survey's Geographical Application Program's Project CARETS. Project CARETS determined the initial data specifications: data were obtained for all but the three western-most counties of Maryland from high-altitude color photography, classified at Level II detail in the U.S. Geological Survey Bulletin 671 system, and mapped at 1:100,000 scale; black and white rectified photo map sheets were prepared from the photography, each covering a 50 by 50 km. area, and used as a base for overlays containing land use information. Incorporating the data in the State base map series, however, required a minor change in scale: final maps were photographically enlarged to 1:126,720 scale (1" = 2 miles). The map projection remained unchanged: CARETS maps are based on a Universal Transverse Mercator projection; Maryland State map products are based on a Lambert Conformal Conic map projection (Figure 2).

The Department of State Planning obtained preliminary draft map manuscripts, provided map editing assistance, and reviewed and evaluated the maps for their utility to the statewide land use plan program, to other programs, and to operational use by the Department's Regional offices. Having these data, their currency, and a major planning program in process, gave the DSP a unique advantage in participating in the forthcoming NASA ERTS-1 research program. Funding of the proposal, "Applications of ERTS and Other Remotely Sensed Data to Integrated State Planning in the State of Maryland" made a practical test of the objectives

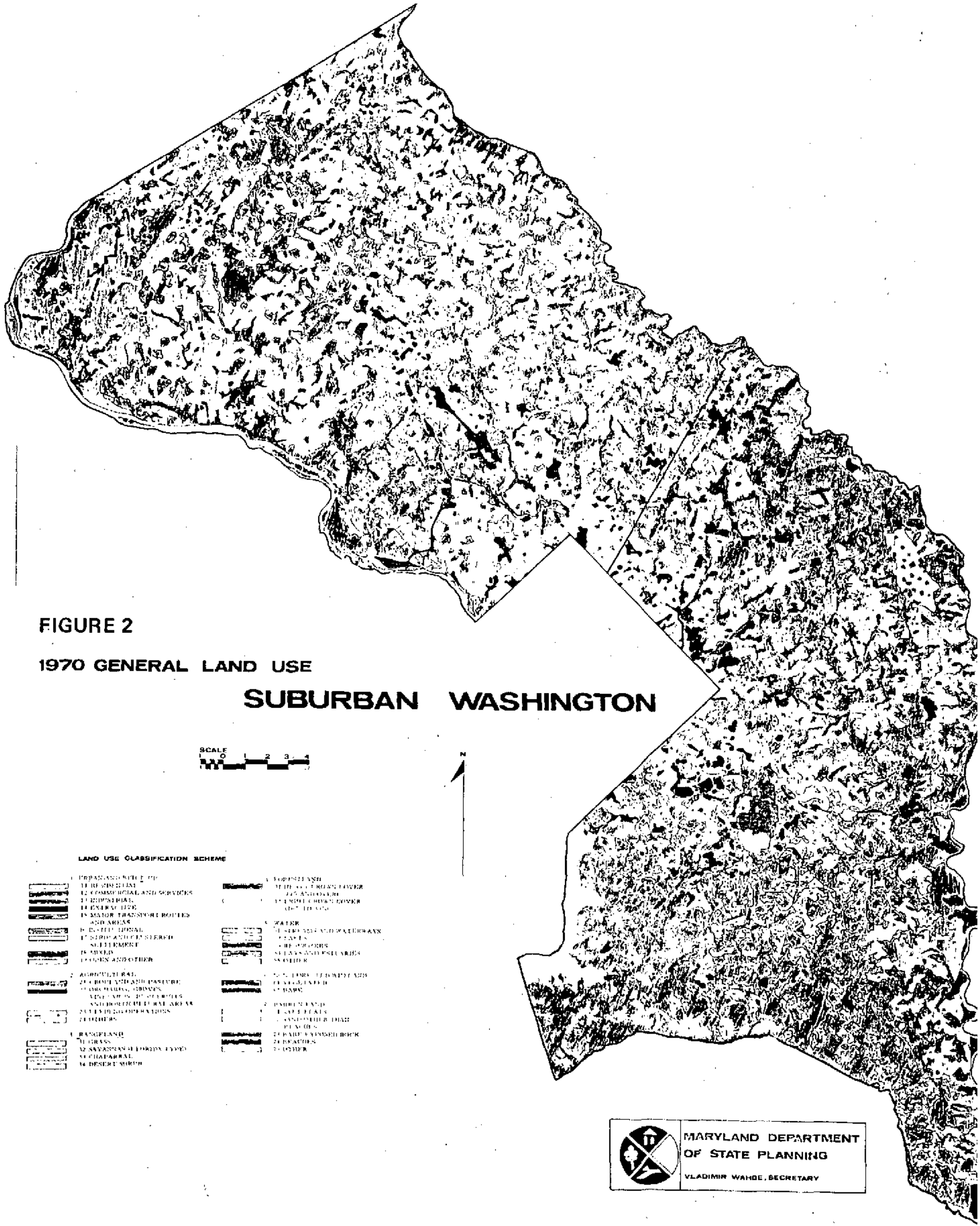


FIGURE 2

1970 GENERAL LAND USE

SUBURBAN WASHINGTON

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of project CARETS and the applications-oriented objectives of the NASA ERTS-1 program a reality; it also gave the DSP an opportunity to obtain useful data and to test state-of-the-art remote sensing and its analytical technology in a practical planning situation.

1972 Land Use Inventory

Since the CARETS land use information did not extend beyond Frederic County, land use data were obtained for the three western-most counties of Maryland (Allegheny, Garrett, and Washington counties) by using other sources and thus to complete the land use information base for the entire State. Existing photography -- USDA-ASCS airphoto index sheets dated 1962 and 1970 -- was used for the initial interpretation which, subsequently, was updated upon the receipt of 70 mm CIR NASA U-2 photography at 1:450,000 scale (pre-ERTS) flown on three separate occasions in 1972. Ground field checks resolved questions of interpretation. Although photo products of equal quality and planimetry of the 1970 CARETS coverage could not be assured using these black and white uncontrolled photos and mosaics, the accuracy of identification and position of boundaries on land use maps were considered satisfactory for use as a planning resource document. In similar instances in other states basic data of any age and resolution are often not even available.

Quantifying and Classifying Land Use Data

Both the statewide land use plan and the simultaneous experiment to evaluate satellite data in this program required quantifying the data below the State and county level according to land use classes and areas that were comparable. Standard means of classifying land use that were internally consistent were necessary, i.e., common to the various sources of information, as well as communicable and compatible with subsequent sources of data (ERTS) and the data collection units of the planning program. These tasks, fundamental to the success of both the project and the experiment, were resolved at that time in the following manner:

- Quantifying areas of land use by class with traditional means has always been time consuming even with electronic counting devices. Such devices were used in the early stages of the project experiment for analyzing the three western-most counties according to electoral districts, divisions of categories ranging in size from 64 acres to 45,000 acres. Experiments showed that the proportions of land uses could be quantified accurately at a relatively small map scale, 1:126,72 compatible with ERTS enlargements (absolute acreage tended to be overestimated) in less than one-third the time necessary to quantify at the 1:62,500 scale. Variations in actual time occurred as a function of parcel size, shape, land use variety,

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and the percentage of the district occupied by any one class (Table 1). The residual method was used to quantify the largest class. Small units were measured and subtracted from the total area of the district; the dominant land use, the remainder, thus accumulates the associated measuring errors.

- Temporal and spatial comparisons cannot be made without classifying the diverse phenomena of land usage into a scheme of abstract groupings. Classification schemes typically are arranged in classes from general to specific by dividing groupings into progressively more detailed groups in hierarchial fashion on the basis of criteria which are common -- usually economic activity. Consequently, one identifies "levels" in a classification scheme that refer to the order of detail contained. The popular U.S.G.S. scheme of Bulletin 671, entitled "A Land Use Classification for Use with Remote Sensor Data," represents a land cover classification according to a planimetric or aerial-orbital perspective, inherently different from the traditional perspective which is a direct line-of-sight or ground based viewpoint. The scheme relies on substitutes for direct observation, e.g., the use of surrogates (discussed more fully in Bulletin 671) as an interpretive technique that has made the credibility issue more real among users yet unfamiliar with the technology. (A summary of data-technology transfer problems encountered in this project and their solutions is presented in Chapter 6).

1973 Land Use Inventory

The CARETS 1970 and Western Maryland 1972 land use maps, classifications, and quantitative data were subjected to a rigorous evaluation by the DSP and local agencies for their utility in a variety of practical planning problems at State, regional, and local levels. They concluded that the maps would be more useful if they contained more detail and were plotted at a larger scale (Figure 3). Earth Satellite Corporation first explored the possiblity of obtaining Level III-IV detail from high-flight imagery for areas classified by the DSP as "critical" planning problems. Several conclusions were obtained: (1) that detail could be obtained for the critical areas though it was unnecessary in all instances; and (2) that the value of detail must be weighted against its cost. Further analysis by the teams of investigators determined that for current programs, particularly plan administration problems, more detail and larger scale maps would be necessary and justify additional effort and expense. In response to this, funds were provided by the DSP to support an expanded mapping effort that covered the entire State.

Effort focused on compiling a Level III (U.S.G.S. classification) land use map from high-flight imagery obtained from the NASA ERTS-1 experiment program. A choice was made between the objectives of the ongoing planning program and the experiment: objectives of the experiment

TABLE 1

ACREAGE PER LAND USE CATEGORY FOR WESTERN MARYLAND COUNTIES			
	ALLEGANY	GARRETT	WASHINGTON
TOTAL ACRES	293,728	427,648	301,440
RESIDENTIAL	7,142	1,115	5,966
RETAIL AND WHOLESALE SERVICES	870	319	1,564
INDUSTRIAL	692	100	512
EXTRACTION	1,743	4,473	589
TRANS., COMM. AND UTILITIES	206	93	1,714
EDUCATIONAL	257	50	1,152
STRIP AND CLUSTERED	5,121	3,507	8,114
MIXED URBAN	-	62	-
OPEN AND OTHER (URBAN)	77	31	77
CROP AND PASTURE LAND	43,340	110,022	177,668
ORCHARDS	1,331	-	9,600
DECIDUOUS FOREST	211,298	301,565	87,213
CONIFEROUS FOREST	1,305	3,245	1,154
RIVERS	-	-	5,938
LAKES	128	517	128
RESERVOIRS	154	2,548	51
BAYS AND ESTUARIES	-	-	-

46

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LAND USE MAP

HOWARD COUNTY

MARYLAND

PREPARED BY

EARTH SATELLITE CORPORATION

FOR THE

MARYLAND DEPARTMENT OF STATE PLANNING

1973

SCALE IN MILES

1 0 1 2 3 4

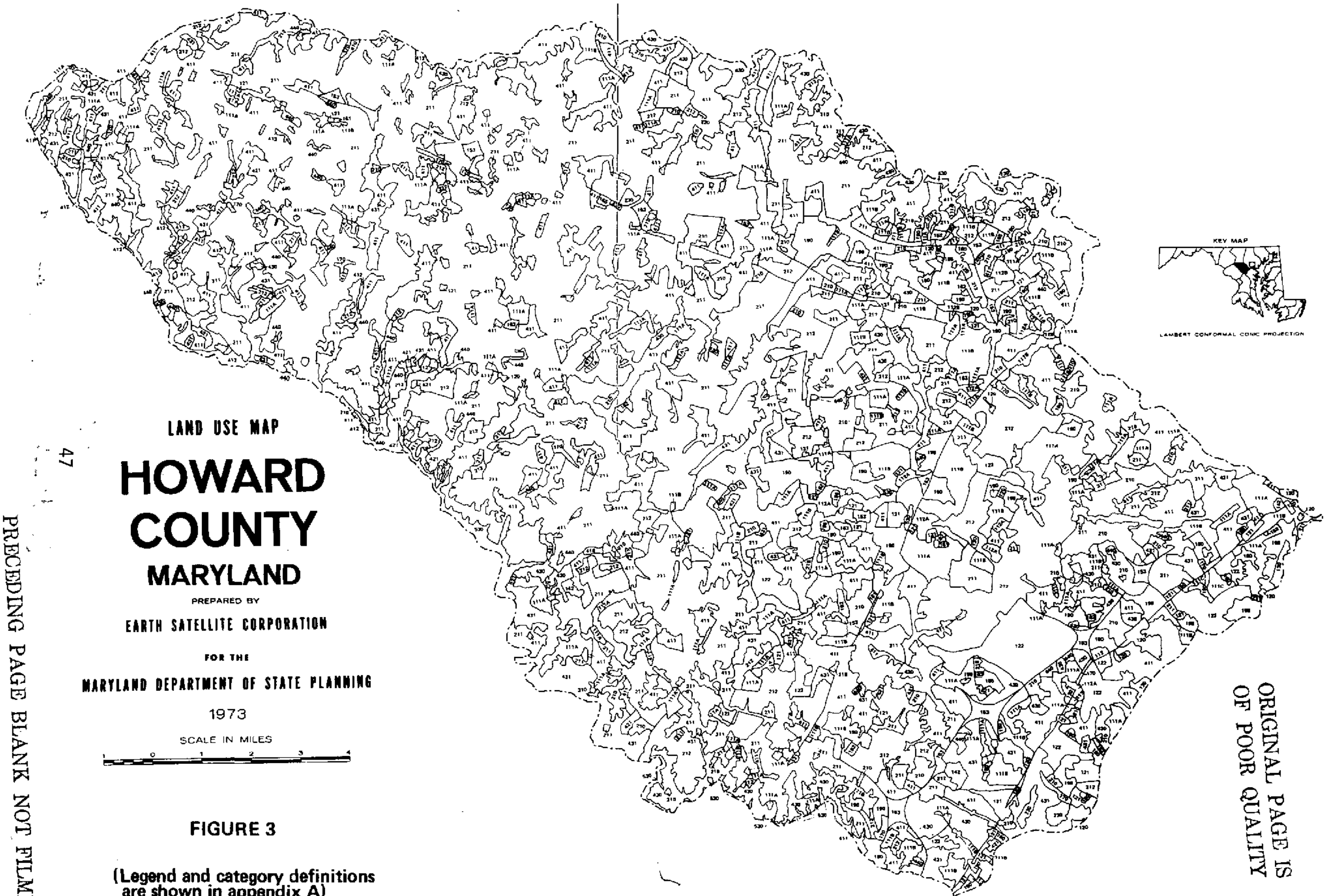

FIGURE 3

(Legend and category definitions are shown in appendix A) would not determine the limits of research and the products that would be obtained. Although Level II data were adequately obtained earlier and could be compared with satellite data, the additional detail and effort were required primarily for purposes of the on-going planning program. Furthermore, the experiment would benefit from more current data of higher quality used as base line information which was supported by funds provided by the State. For these reasons the effort to collect additional data was justified within the bounds of the experiment.

ERTS-1 Based Land Use Inventory

The comprehensive statewide planning program in process offered an excellent test of the utility of satellite data in practical use. In this program, where demands and sources for information were clearly established by tradition and past experience, opportunity existed for comparing the merits of each form of data with ERTS-1 data, examining their relative utilities, and identifying the particular area of analysis where each is suited. Furthermore, testing ERTS data in this context permitted analytical techniques to be explored and tested across the entire breadth of a small state (10,577 sq. mi.) with diverse cultural and physical landscapes. Lastly, the existence of a detailed land use map (1973) provided base line data for evaluating the accuracy of classifications from ERTS-1 data and for the development of comparative production costs.

Satellite data in both image and digital formats served as the basis for two tasks: (1) information acquisition, and (2) technique development. ERTS-1 information was divided into two types, each of which constitutes a separate application area: (1) information for regional and statewide use; and (2) specific information for sub-regional and local use. Techniques developed in obtaining general types of information have been used to acquire information for specific, detailed studies. This section contains an examination of land use data and products obtained from ERTS-1 applied to regional and statewide purposes, and includes an analysis of the techniques developed in that application. Subsequent sections of this report will treat the acquisition of data other than land use, and applications of land use data in detailed studies.

Statewide ERTS Mosaic: The ERTS-1 mosaic of Maryland was initially prepared at the specific request of the Governor of Maryland, the Honorable Marvin Mandel, as shown in Figure 4. Subsequently, the mosaic has served several purposes and provided for a variety of ERTS data applications and interpretive studies.

The process of developing a statewide mosaic employed a relatively uncommon technique which is uniquely suited for multispectral ERTS images -- the color dye transfer process. Eight images compiled from five ERTS passes spaced over nine months (September, 1972 to May, 1973) were necessary to provide sufficient cloud free imagery of a spectral character suitable for mosaicking.

One of the primary applications of the mosaic was communication and education. Attention was called to the sophisticated tools available to the planning community at large, to the specific objectives of the NASA ERTS program and, in the capacity of an agent of innovation diffusion, to the products and results of the experiment. This objective was met by the request of the Governor and his subsequent distribution of ERTS mosaic products to local jurisdictions. Two overlays were initially prepared: one shows County boundaries and names; the other identifies easily recognized geographic places such as rivers, mountains, and cities. Enlargements were made at 1:500,000 scale with the overlay of County boundaries, and county enlargements at approximately 1:300,000 scale with the location overlays.

Other applications of ERTS mosaics were based on their utility as a broad overview of diverse physical landscapes of the State and region. For example, the mosaic of Maryland has provided a base image map for compiling and analyzing data for various interpretive studies. A generalized State Land Use Map gains meaning and value when compared with the mosaic. Linear patterns and networks, such as the Preliminary Geologic Lineament Map (as well as transportation lines and streams) can best be presented as an overlay on a quality controlled ERTS mosaic.

ERTS Land Use Inventory: ERTS imagery has been employed in land use mapping and updating maps both at statewide and regional levels. Specific attention was directed toward extracting Level I land use information for one point in time -- January, 1973 (Figure 4). January was used primarily because it was the only time the entire State was imaged essentially cloud free at the time of the analysis. While these data were adequate as a basis for interpretation, data from other dates would have considerable additive value. Subsequent efforts were directed towards demonstrating the capability of extracting more detailed information from the satellite imagery. These studies were conducted primarily to determine the utility of ERTS-1 data for preparing and updating land use maps based on the land use classification system adopted by Maryland. These efforts are described in the "critical areas" portion of this report.

Image interpretation for the Generalized Land Use Map was performed on 1:250,000 enlargements of MSS Bands 5 and 7. Data extraction involved two steps: all water, wetlands, and barren land were plotted on acetate overlays placed on MSS Band 7; this overlay was then placed on a MSS Band 5 enlargement and all forest, agriculture, and urban and built-up lands were plotted. ERTS color composites (1:500,000 scale) were used to separate urban, suburban, and agricultural patterns, particularly in the Baltimore-Washington corridor. High altitude color infrared aerial photography provided "ground truth" in the limited instances where it was deemed necessary. Illustrations of the resulting Generalized Land Use map for display and presentation purposes were made by photographing colored, mosaicked paper diazo prints of the overlays (maps).

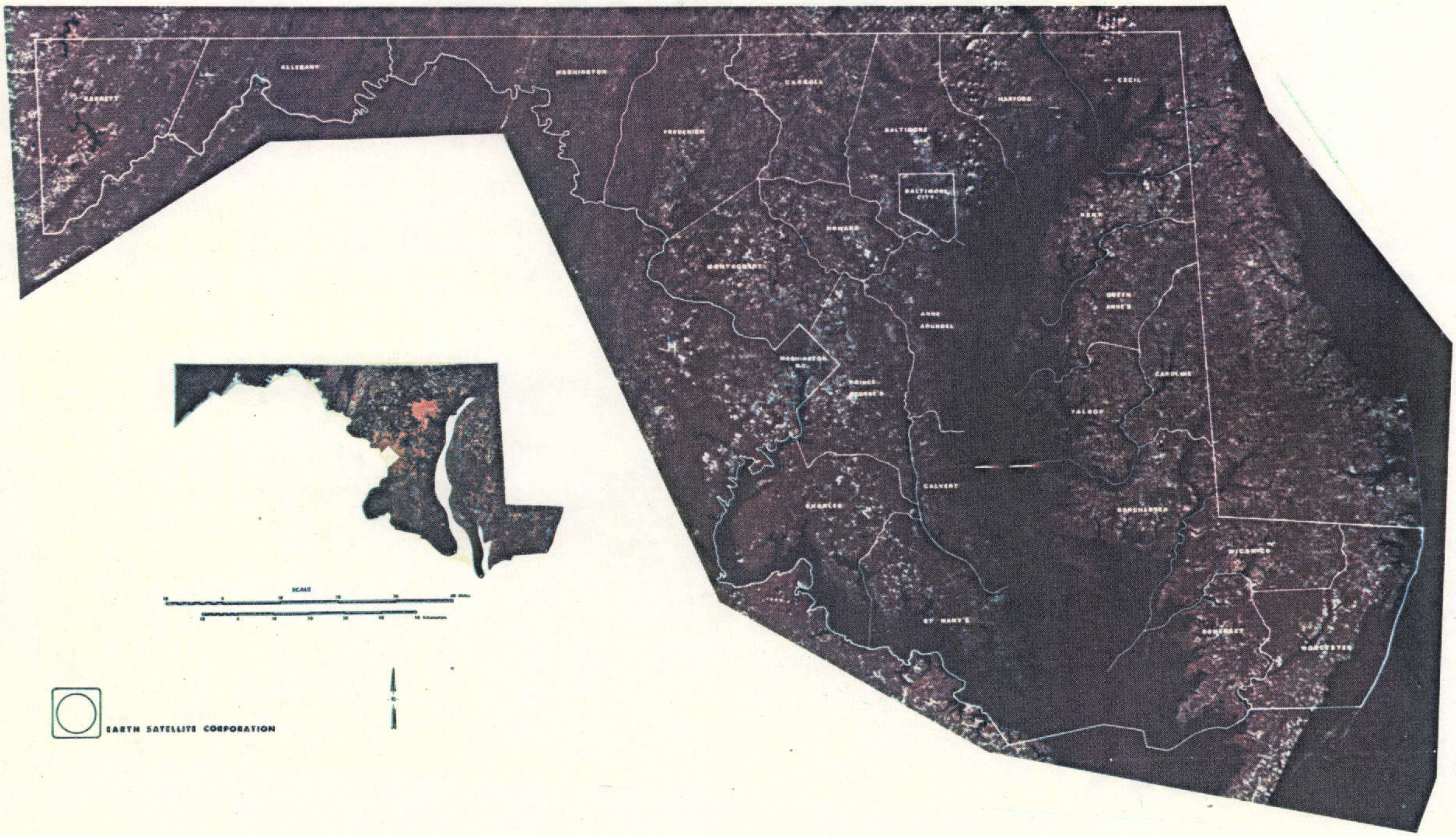

FIGURE 4 - 1973 Maryland General Land Use Patterns and ERTS-1 Mosaic

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Several significant results were reported, the most significant of these were:

(1) ERTS-1 images can be used to develop accurate land use maps of Level I and some Level II categories on an annual or semi-annual basis, with little or no underflight support;

(2) When color is used as a discriminant, Level II categories can be mapped outside urban areas and, to a lesser degree, within large urban regions;

(3) For general land use mapping at the scale and accuracy represented (no quantitative measurement of accuracy was possible because of the way the map was prepared), there is no other <u>traditional</u> land use inventory technique (field survey, photo interpretation, etc.), that is cost competitive. The map of approximately 12,300 square miles was prepared in approximately 18 man-days (average, 85 $mi.^2/hr$);

(4) The analysis has led to subsequent investigations to develop techniques for refining land use maps from ERTS products on a regional level using both enhanced imagery and ERTS CCT's.

These capabilities are combined with certain limitations:

(1) Band 7 can be used to identify water, barren land, and wetlands at virtually any time of the year except in winter when snow cover affects the accuracy of wetland delineation (increases errors of omission).

(2) Forest lands were easily discerned on Band 5 but, in some instances, were difficult to separate from agriculture without relying on highly skilled interpreters.

(3) Errors occur most often in discriminating agriculture, particularly harvested fields, bare soil, or senescent short grasses, and urban and built-up land. The most common types of error were classifying the latter as agriculture, and classifying too few areas as urban. It has subsequently been determined that these errors can be reduced by using false color composites of MSS Bands 4, 5, and 7 of multiple dates, but at increased cost.

(4) While winter coverage (January) provided excellent discrimination of forested lands (in many cases the separation of hardwoods and conifers), snow and accentuated shadows from the low winter sun angle were generally a disadvantage. As a result, forests on south and east-facing slopes were confused with agriculture; on north and west facing slopes, shadows made accurate classifications of land use difficult. Whereas snow helps differentiate thick stands of trees from agriculture, sparse

Furthermore, the preparation of ERTS land use maps expedited some of the more specialized studies which were carried out later in the project; specifically, the analysis of the ERTS-1 digital tapes and the design of the State's geobase information system (both discussed later).

Digital Analysis of ERTS-1 Data

The need of regional and statewide land use information by land use planners required to develop land use plans and to monitor their influence on development has created interest within the planning community in synoptic and periodic imaging systems, particularly those which are linked with automated analytical tools. Two technologies, satellite remote sensing and multispectral digital analysis, show substantial potential to provide this information in a manner sufficiently cost-effective to influence the ways planners collect data.

A test was made to apply ERTS-1 digital data and electronic processing techniques for mapping categories of land use. Additional importance was given to this experiment because of the fact that the State of Maryland was undertaking development of an automated geobase information system, one of whose important data items was land use. Consequently, the outcome of this experiment would demonstrate two capabilities: to provide useful information cost-effectively, and to provide data that are compatible with the automated system that can be used to update the system.

The Test Site: The following discussion focuses on the multispectral analysis of ERTS-1 digital data for a test site selected from the highly diversified land uses of the Baltimore-Washington corridor, a rural-urban transition zone. The site measures approximately 3.5 miles by 14.5 miles (51 sq. mi.) which corresponds to a 100 by 300 pixel area on ERTS-1 data. Land usage for this area had previously been mapped from Skylab imagery and high altitude aerial photography.

The northern part of the site contains the Columbia Industrial Park and in the eastern part lies the planned community of Columbia. Several sand and gravel pits and stone quarries are located along major thoroughfares, e.g., Route 95 and the Baltimore-Washington Parkway. The Beltsville Agricultural Research Center provides a substantial area of agricultural land. Numerous commercial centers within this area can be found at Beltsville, Laurel, and at Columbia. Residential land usage is extensive, and many areas of residential development and land cleared for unidentified development can also be found. This broad diversity is precisely why the site provides an excellent test for the combined technologies.

Data Processing Methodology: ERTS-1 imagery acquired on July 8, 1973, over the Baltimore-Washington corridor was selected for this anlaysis. The high altitude aircraft imagery acquired nearest to the date of the ERTS overpass was flown on June 14, 1973 and was used to select training sets and document results.

Computer compatible tapes from the July 8 imagery were reformatted through the EarthSat standard reformat program and a shade print was prepared of the test site (Figure 5). Training sets and test sites were identified on aircraft imagery largely on the basis of size and spectral representativeness of the land use class being considered. Six classes initially were selected: single family residential, multi-family residential, commercial, evergreen forest, deciduous forest, agriculture, bare ground, and water. Training and test areas were transferred from the photography to the shade print (a line-printer map) to determine shade characteristics which describe each land use class for subsequent analysis.

The LARSYS maximum likelihood classification system was used to analyze the above data. LARSYS consists of a package of statistics used within the computer to calculate the probability that a pixel's (grey levels) belongs to a specific class of objects with a defined set of spectral characteristics, and assigns the pixel to the class with the highest probability. The LARSYS system was developed at Purdue University for use with multispectral digital data from ERTS-1 and other remote sensing systems. Using this system, statistical parameters were calculated for the mean spectral signature in each ERTS-1 channel, standard deviation, covariance between channels, and divergence (divergence is a statistical measure of the separability of training classes) for each land use class based on an assumed Gaussian distribution. Outputs from this procedure are represented as histograms of each training class (Figure 6), which show the distribution of data points in various channels. Coincident spectral plots were also generated which illustrate the mean spectral response, plus or minus one standard deviation (Figure 7). From these plots, analysts can obtain an indication of the spectral signature characteristics and their "statistical quality" in each class, as well as obtain an indication of the spectral separability of the training classes.

Spectral plots are inherently one-dimensional, illustrating shade variations within one channel that cannot be transformed easily into a multi-dimensional analysis. The divergence measure, embedded in -n- space and assuming normally distributed training set data, yields an estimate of the interclass separability and allows inference of the expected classification accuracy (divergence tests interclass separability without resorting to classification). A divergence program implemented in this experiment outputs divergence values for all possible combinations of spectral bands and land use classes. Good separability is indicated in Tables 3 and 4 by a divergence value greater than 1600. The results of these analyses led to further refinement of the training sets and photo interpretation of the aircraft "ground truth" imagery.

Once suitable training sets were established, the data were further analyzed using LARSYS multispectral maximum likelihood classification algorithms. Discrimination between classes is accomplished by establishing decision boundaries in four-dimensional spectral space derived from the spectral signature statistics generated for each training set in each

FIGURE 5: ERTS Shade Print of Baltimore / Washington Test Site

```
        BALTIMORE-WASHINGTON CORRIDOR    JULY 8,1973   E1350-15192

CLASS....SINGLFAM           TOTAL NUMBER OF SAMPLES...     86

HISTOGRAM(S)

CHANNEL  1        0.50 -  0.60  MICROMETERS

   EACH * REPRESENTS   3  POINT(S).

        42 I
        39 I
        36 I
        33 I
        30 I            2
        27 I           1*1
        24 I           ***
        21 I           ***
        18 I           ***
        15 I           ***
        12 I           ***
         9 I           ***
         6 I          ****
         3 I          **** 1
           I----+----+----+----+----+----+----+----+----+
         14.50                  54.50                94.50

CHANNEL  3        0.70 -  0.80  MICROMETERS

   EACH * REPRESENTS   2  POINT(S).

        28 I
        26 I
        24 I
        22 I                  11
        20 I                  **
        18 I                 1**
        16 I                 ***
        14 I                 ***1
        12 I                 ****
        10 I                 ****
         8 I                 *****
         6 I                ******
         4 I                ******
         2 I                ******
           I----+----+----+----+----+----+----+----+----+
         14.50                  54.50                94.50

CHANNEL  2        0.60 -  0.70  MICROMETERS

   EACH * REPRESENTS   2  POINT(S).

        28 I
        26 I         1
        24 I         **
        22 I         **
        20 I         **
        18 I         **
        16 I       11**
        14 I       ****
        12 I       ****
        10 I       ****
         8 I       ****
         6 I       ****
         4 I      1****1
         2 I      ******  1
           I----+----+----+----+----+----+----+----+----+
         14.50                  54.50                94.50

CHANNEL  4        0.80 -  1.10  MICROMETERS

   EACH * REPRESENTS   3  POINT(S).

        42 I
        39 I
        36 I
        33 I       2
        30 I      2*
        27 I      **
        24 I      **
        21 I      **
        18 I      **
        15 I      ***
        12 I      ***
         9 I      ***
         6 I     1****
         3 I     *****
           I----+----+----+----+----+----+----+----+----+
         14.50                  54.50                94.50
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FIGURE 6: LARSYS Training Class Histograms - Residential

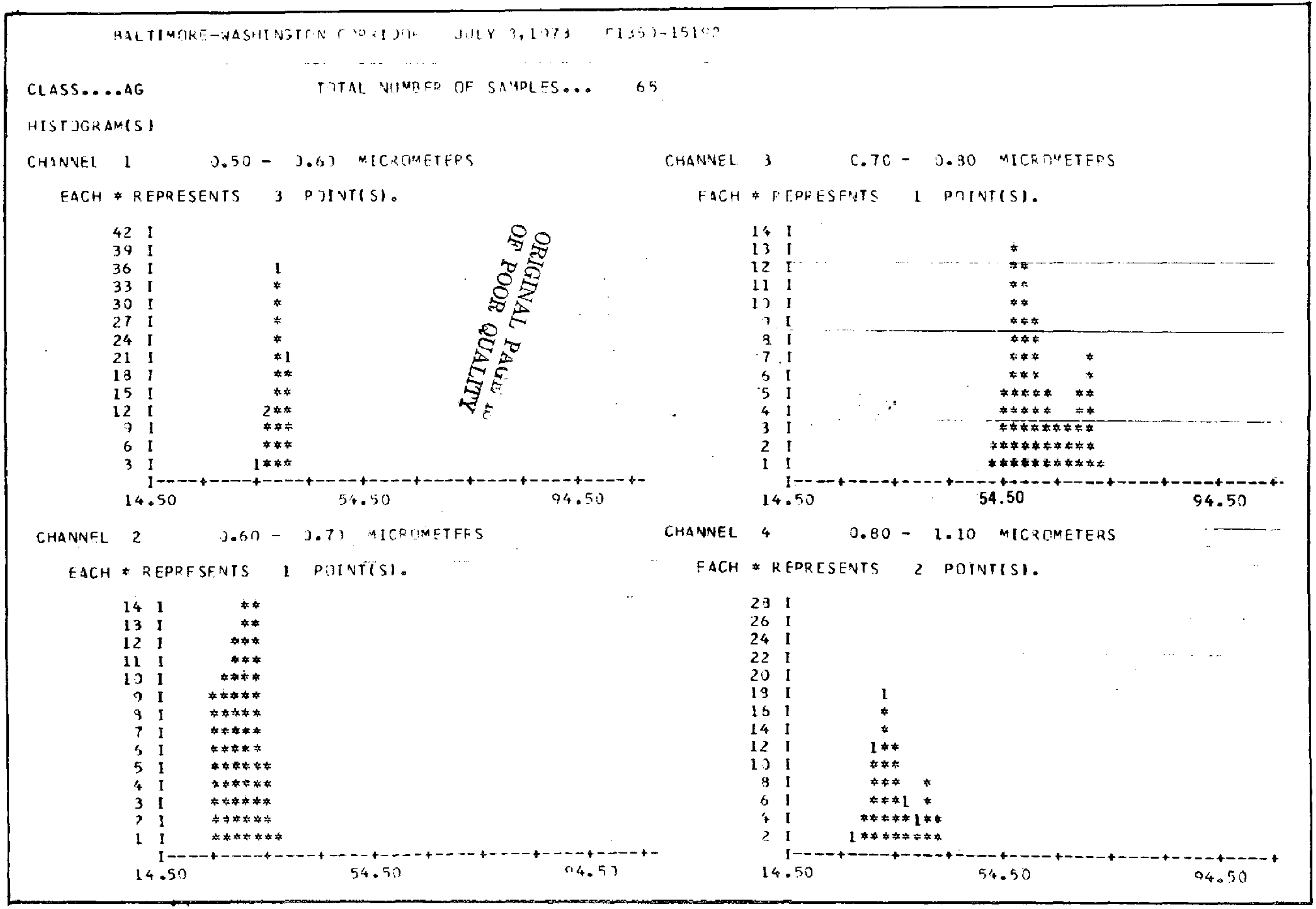

FIGURE 6: LARSYS Training Class Histograms - Agriculture

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BALTIMORE-WASHINGTON CORRIDOR    JULY 8,1973    E1350-15192

CLASS....DECIDUOS          TOTAL NUMBER OF SAMPLES...    42

HISTOGRAM(S)

CHANNEL  1        0.50 -  0.60  MICROMETERS

   EACH * REPRESENTS   2  POINT(S).

28 I
26 I        1
24 I        *
22 I        *
20 I        *
18 I        *
16 I        **
14 I        **
12 I        **
10 I        **
 8 I        **
 6 I        **
 4 I        **
 2 I       1**
   I----+----+----+----+----+----+----+----+----+
 14.50               54.50               94.50

CHANNEL  3        0.70 -  0.80  MICROMETERS

   EACH * REPRESENTS   1  POINT(S).

14 I
13 I
12 I
11 I
10 I                  *
 9 I                  *
 8 I                  ***
 7 I                  ***
 6 I                  ***
 5 I                  ***
 4 I                 **** *
 3 I                 **** *
 2 I                ***** ***
 1 I                **********
   I----+----+----+----+----+----+----+----+----+-
 14.50               54.50               94.50

CHANNEL  2        0.60 -  0.70  MICROMETERS

   EACH * REPRESENTS   3  POINT(S).

42 I
39 I
36 I   1
33 I   *
30 I   *
27 I   *
24 I   *
21 I   *
18 I   *
15 I   *
12 I   *
 9 I   *
 6 I  2*
 3 I 2**1
   I----+----+----+----+----+----+----+----+----+
 14.50               54.50               94.50

CHANNEL  4        0.80 -  1.10  MICROMETERS

   EACH * REPRESENTS   1  POINT(S).

14 I
13 I       *
12 I       *
11 I       * *
10 I       * *
 9 I       * *
 8 I       * *
 7 I       ***
 6 I       ***
 5 I       ****
 4 I       ****
 3 I       ****
 2 I      *******
 1 I      *******
   I----+----+----+----+----+----+----+----+----+-
 14.50               54.50               94.50
```


FIGURE 6: LARSYS Training Class Histograms - Deciduous Forest

```
      BALTIMORE-WASHINGTON CORRIDOR    JULY 8,1973    E1350-15192

CLASS....CONIFER            TOTAL NUMBER OF SAMPLES...    21

HISTOGRAM(S)

CHANNEL  1       0.50 -  0.60  MICROMETERS          CHANNEL  3       0.70 -  0.80  MICROMETERS

   EACH * REPRESENTS   1  POINT(S).                    EACH * REPRESENTS   1  POINT(S).

        14 I                                                 14 I
        13 I                                                 13 I
        12 I                                                 12 I
        11 I       *                                         11 I
        10 I       *                                         10 I
         9 I       **                                         9 I
         8 I       **                                         8 I
         7 I       **                                         7 I
         6 I       **                                         6 I           *
         5 I       **                                         5 I           *
         4 I       **                                         4 I           *
         3 I       **                                         3 I         ***  *
         2 I       **                                         2 I       ***** **
         1 I       ***                                        1 I       ***** **
           I----+----+----+----+----+----+----+----+----       I----+----+----+----+----+----+----+----+
        14.50               54.50               94.50        14.50               54.50               94.50

CHANNEL  2       0.60 -  0.70  MICROMETERS          CHANNEL  4       0.80 -  1.10  MICROMETERS

   EACH * REPRESENTS   1  POINT(S).                    EACH * REPRESENTS   1  POINT(S).

        14 I  *                                              14 I
        13 I  *                                              13 I
        12 I  *                                              12 I
        11 I  *                                              11 I
        10 I  *                                              10 I
         9 I  *                                               9 I
         8 I  *                                               8 I
         7 I  *                                               7 I
         6 I  *                                               6 I
         5 I  *                                               5 I   *
         4 I  **                                              4 I  *** *
         3 I ***                                              3 I  *** *
         2 I ***                                              2 I  ******
         1 I ***                                              1 I  ******
           I----+----+----+----+----+----+----+----+----       I----+----+----+----+----+----+----+----+
        14.50               54.50               94.50        14.50               54.50               94.50
```

FIGURE 6: LARSYS Training Class Histograms - Coniferous Forest

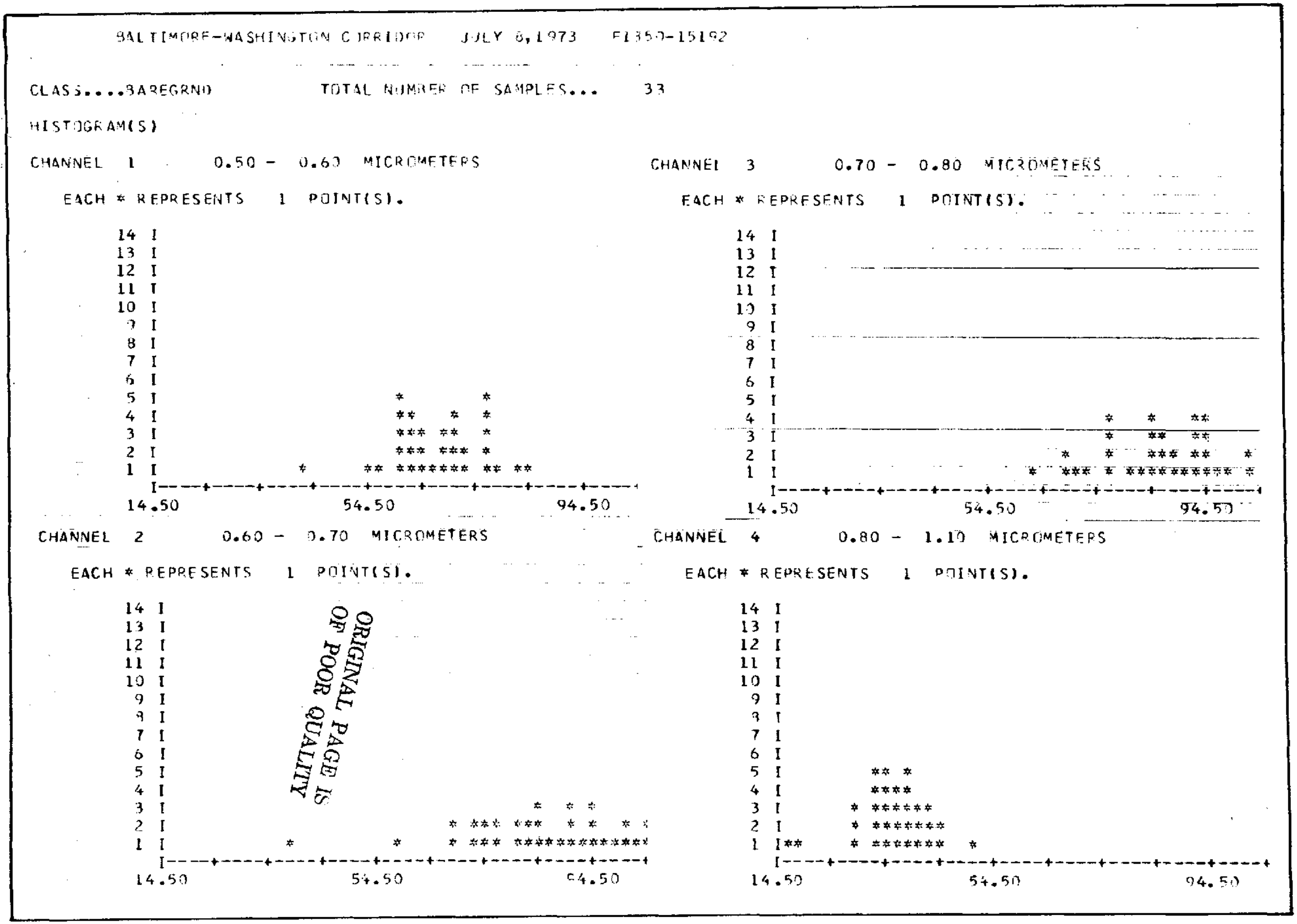


FIGURE 6: LARSYS Training Class Histograms - Bare Ground

```
       BALTIMORE-WASHINGTON CORRIDOR   JULY 8,1973   E1350-15192

CLASS....WATER                 TOTAL NUMBER OF SAMPLES...    11

HISTOGRAM(S)

CHANNEL  1      0.50 - 0.60  MICROMETERS          CHANNEL  3      0.70 - 0.80  MICROMETERS

  EACH * REPRESENTS   1  POINT(S).                  EACH * REPRESENTS   1  POINT(S).

       14 I                                                14 I
       13 I                                                13 I
       12 I                                                12 I
       11 I                                                11 I
       10 I                                                10 I
        9 I                                                 9 I
        8 I         *                                       8 I
        7 I         *                                       7 I
        6 I         *                                       6 I
        5 I         *                                       5 I
        4 I         *                                       4 I  *
        3 I         *                                       3 I **
        2 I         **                                      2 I **
        1 I        ***                                      1 I ****  *    *
          I----+----+----+----+----+----+----+----+-          I----+----+----+----+----+----+----+----+----+
        14.50               54.50               94.50       14.50               54.50               94.50

CHANNEL  2      0.60 - 0.70  MICROMETERS          CHANNEL  4      0.80 - 1.10  MICROMETERS

  EACH * REPRESENTS   1  POINT(S).                  EACH * REPRESENTS   1  POINT(S).

       14 I                                                14 I
       13 I                                                13 I
       12 I                                                12 I
       11 I                                                11 I
       10 I                                                10 I*
        9 I                                                 9 I*
        8 I                                                 8 I*
        7 I                                                 7 I*
        6 I                                                 6 I*
        5 I                                                 5 I*
        4 I  **                                             4 I*
        3 I ***                                             3 I*
        2 I ***                                             2 I*
        1 I ***                                             1 I*  *
          I----+----+----+----+----+----+----+----+-          I----+----+----+----+----+----+----+----+----+
        14.50               54.50               94.50       14.50               54.50               94.50
```

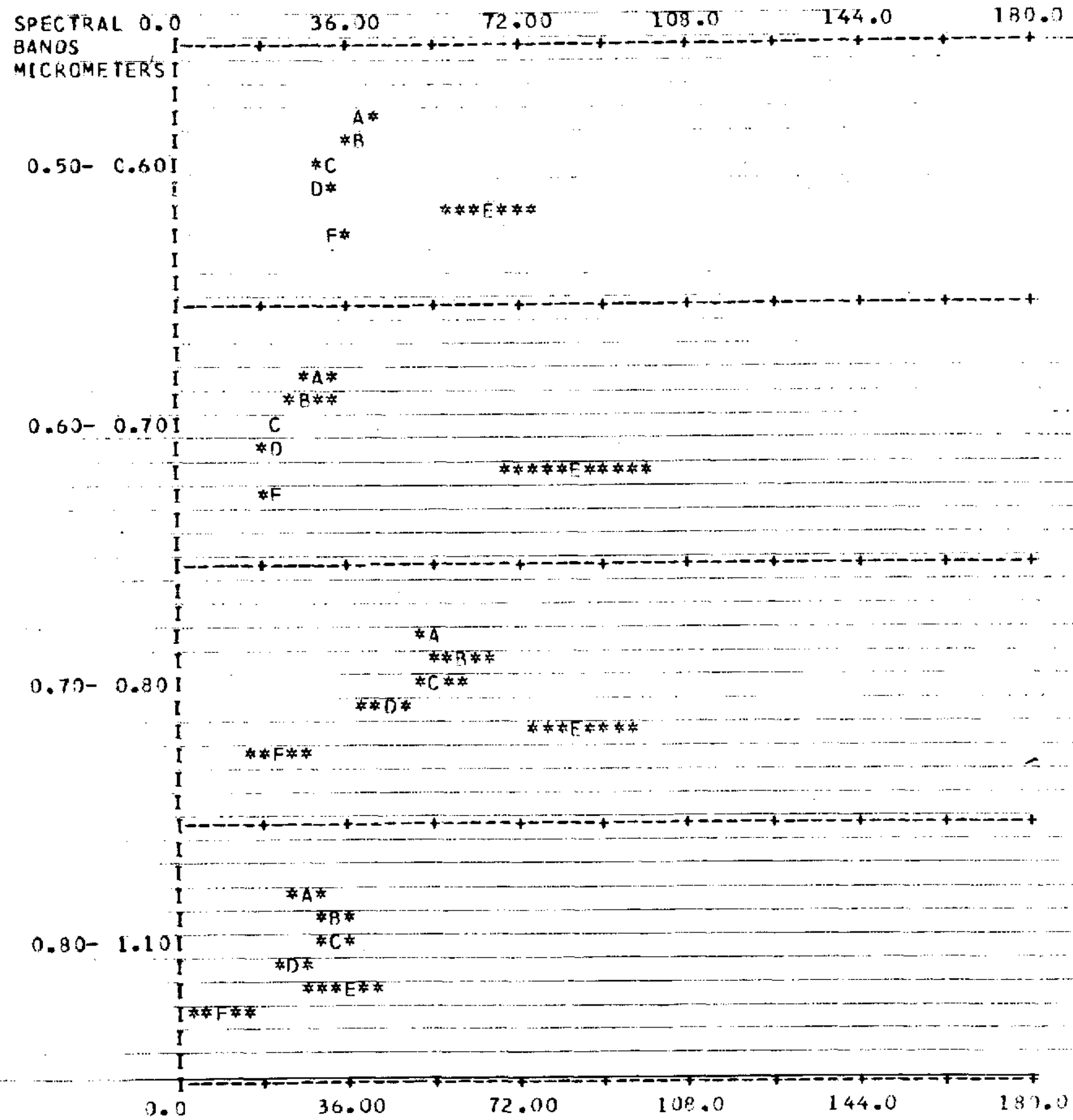
FIGURE 6: LARSYS Training Class Histograms - Water

FIGURE 7: LARSYS Training Class Spectral Plots

BALTIMORE-WASHINGTON CORRIDOR   JULY 8,1973   E1350-15192

COINCIDENT SPECTRAL PLOT (MEAN PLUS AND MINUS ONE STD. DEV.) FOR CLASS(ES)

LEGEND
- A = CLASS 1 SINGLFAM
- B = CLASS 2 AG
- C = CLASS 3 DECIDUOS
- D = CLASS 4 CONIFER
- E = CLASS 5 BAREGRND
- F = CLASS 6 WATER



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spectral band. Individual pixels are assigned to one of the defined training set classes, which are then displayed individually as classes on a single printout or combined with other classes.

Displaying the data frequently requires restricting the classification of data points by thresholding techniques which reject data points assigned to a class which do not look sufficiently like the class. Threshold values established at the tails of the distribution essentially cause the outermost points in a class distribution to be deleted. By this process, the spectral characteristics which best describe a particular class are analyzed. The effect of high threshold values generally is to reduce commission errors, but often at the expense of increasing omission errors that result when there is substantial interclass variability in signature. Selection of threshold values is based entirely on the experience and careful judgment of within-class and between-class variability.

The multispectral classification algorithm used in this analysis assumes the signals received by the ERTS-1 multispectral scanner have multivariate normal distributions. Histograms for each spectral band for the training classes (Figure 6) show this is not always the case. It is difficult to determine whether departures from the distribution are significant without conducting non-normality tests (which have not been performed on these data). An additional discriminant analysis program could also be used to provide analytical information on channel selection and accuracy associated with the addition of each band.

The computer recognition map shown, in Figure 8, includes areas used in establishing the training set statistics and decision boundaries used in the classification process. On this map the pixels classified within the training sets are classified correctly in some cases and incorrectly in others. Classification performance within training sets is shown in Table 2 for each class at the given threshold values.

The classification performance is expressed as percent (%) correct identification and percent (%) commission error, where:

$$\%\ \text{Correct} = \frac{\#\ \text{of pixels correctly identified as being in a class}}{\text{total}\ \#\ \text{of pixels in that class in the test area}}$$

$$\%\ \text{Commission} = \frac{\#\ \text{of pixels incorrectly identified as belonging to a class}}{\text{total}\ \#\ \text{of pixels identified as belonging to that class}}$$

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GROUND TRUTH	TRAINING CLASS CLASSIFICATION & CLASS THRESHOLD								
	RESIDENTIAL 30%	AGRICULTURE 30%	DECIDUOUS 15%	EVERGREEN 15%	BARE GROUND 7%	WATER 7%	THRESHOLD	TOTAL	PERCENT CORRECT
SINGLE FAMILY RESIDENTIAL	76	9					1	86	88
AGRICULTURE	8	56					1	65	86
DECIDUOUS			40	1			1	42	95
EVERGREEN				21				21	100
BARE GROUND					32		1	33	97
WATER						11		11	100
TOTAL	84	65	40	22	32	11	4	258	
PERCENT COMMISSION	9	14	0	4	0	0			

TOTAL CORRECT - 236   OVERALL PERFORMANCE - 91.5

TABLE 2: LARSYS Training Class Performance

Training class performance indicates an overall performance of 91.5 percent correct identification. Classification results were displayed on black and white film using the Litton digital film recorder, in color composite form from the Litton prints (Figure 9), and in line printer output (Figure 8).

Analysis: Preliminary analysis of the histograms and coincident spectral plots indicated that two land use classes -- multi-family residences and commerce -- were spectrally diverse and would be difficult to separate from other classes. As a result, both land use types were eliminated from this test.

Histograms for agriculture indicate a bimodal distribution in the infrared bands (MSS 6 and 7), suggesting variability in crop development (contained in Figure 7). Agriculture was spectrally distinct from other land use classes, having training sets of high quality, which is reflected in the accuracy of figures associated with training class performance. Yet, only 86 percent correct identification was obtained in the agriculture training class. Deciduous and evergreen forests, bare ground, and water training classes also have "good" training sets and relatively low omission and commission errors. This level of performance in agriculture is likely to be the result of improper training class selection, or large within-class and between-class variations in signatures. Since this training class typically was confused with single family residences, it is likely that incorrect identifications contain areas of substantial tree cover and surrounding lawns. Figure 7 also illustrates the difficulty of assessing the separability of several classes using four-channel data.

Divergence tests can be used to provide an estimate of interclass separability, and to help identify the contribution each channel makes toward the separation of a given pair of classes using four-channel data. An optimum combination of channels can be selected and ranked using the highest average divergence value or highest minimum value. When two or more classes are felt to be spectrally similar, the highest minimum divergence value would be used to select the optimum combination of channels. For example, deciduous, evergreen, and mixed forest classes generally appear similar spectrally, thus requiring the highest minimum divergence value to combine channels so that these classes may be separated. Conversely, if a set of classes are to be identified which are spectrally dissimilar, combinations of spectral bands would be selected which provide the highest average divergence value. Generally, the fewer the channels used, the lower the computer costs.

Average divergence values and minimum divergence values are presented in Table 3 for all classes for various combinations of spectral bands: combinations of two, three, and all four. Average divergence values of 1903 associated with Bands 4 and 7 suggests good separation of all classes using these spectral regions. The minimum divergence value, 1280, suggests, however, poor to fair separability. Both divergence values suggested that all four spectral bands were required for the classes used in training. The matrix shown in Table 4 shows divergence values for all pairwise combinations of training classes that were developed from spectral signature statistics in all four bands.

TABLE 3 - AVERAGE AND MINIMUM DIVERGENCE VALUES FOR ALL SPECTRAL BAND COMBINATIONS

Combination of Spectral Bands	Average Divergence	Minimum Divergence
4,7	1903	1280
4,6	1899	1266
5,6	1883	1121
4,5	1737	376
6,7	1722	945
4,5,7	1931	1343
4,5,6	1927	1310
4,6,7	1919	1325
5,6,7	1914	1267
4,5,6,7	1944	1430

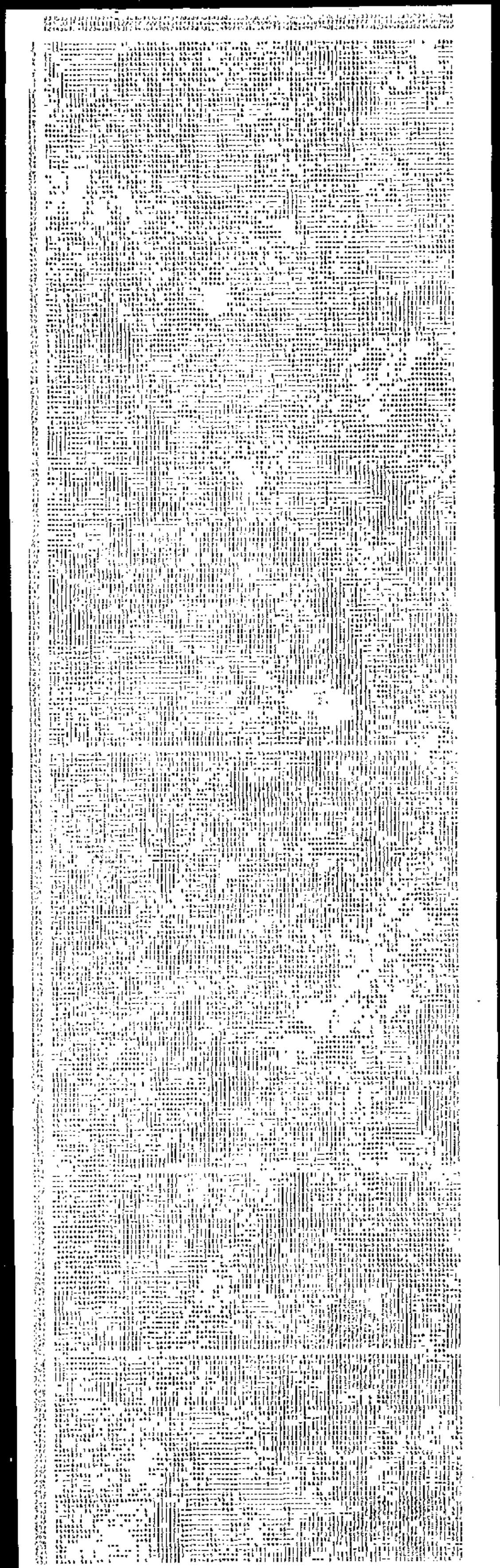

FIGURE 8

MULTISPECTRAL CLASSIFICATION RESULTS

BALTIMORE-WASHINGTON CORRIDOR

ERTS MSS DATA JULY 8, 1973 , E-1350-15192

BAND 4, 0.5 - 0.6 UM, GREEN
BAND 5, 0.6 - 0.7 UM, RED
BAND 6, 0.7 - 0.8 UM, NEAR IR
BAND 7, 0.8 - 1.1 UM, NEAR IR

LEGEND

SYMBOL	CLASS	THRESHOLD PERCENT
$	RESIDENTIAL	30
–	AGRICULTURAL	30
I	DECIDUOUS FOREST	15
E	CONIFEROUS FOREST	15
#	BARE GROUND	7
W	WATER	7

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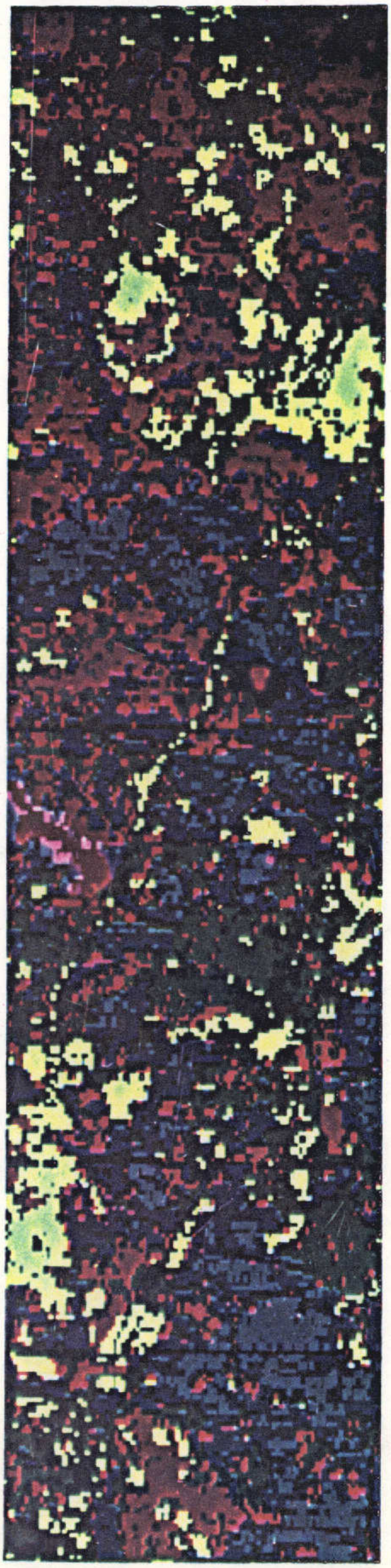

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FIGURE 9 - LARSYS Multispectral Color Classification Results - Baltimore / Washington Test Site

Photographically rendered color computer map of classification results as shown in Figure 8 of the test site shown photographically in Figure 15. Colors represent the following classes

Dark Green	Residential
Red	Agriculture
Dark Blue	Deciduous Forest
Light Blue	Coniferous Forest
Light Green	Bare Ground
Orange	Water
Black	Unclassified

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	SINGLE FAMILY	AGRICULTURE	DECIDUOUS	CONIFEROUS	BARE GROUND
SINGLE FAMILY					
AGRICULTURE	1430				
DECIDUOUS	2000	1999			
CONIFEROUS	2000	2000	1731		
BARE GROUND	2000	2000	2000	2000	
WATER	2000	2000	2000	2000	2000

AVERAGE DIVERGENCE = 1944 MINIMUM DIVERGENCE = 1430

TABLE 4: Divergence Between all Pairwise Class Combinations Using 4 Channel Data

		TEST CLASS CLASSIFICATION AND CLASS THRESHOLD								
		RESIDENTIAL 30%	AGRICULTURE 30%	DICIDUOUS 15%	EVERGREEN 15%	BARE GROUND 7%	WATER 7%	THRESHOLD	TOTAL	PERCENT CORRECT
GROUND TRUTH	SINGLE FAMILY RESIDENTIAL	147	6					17	170	86
	AGRICULTURE	7	42	5				9	63	67
	DECIDUOUS		4	65				5	74	88
	EVERGREEN			2	6			1	9	67
	BARE GROUND	1				69		8	78	88
	WATER						17	1	18	94
	TOTAL	155	52	72	6	69	17	41	412	
	PERCENT COMISSION	5	24	11	0	0	0			

TOTAL CORRECT - 346 OVERALL PERFORMANCE - 84.0

TABLE 5: LARSYS Test Class Performance

Measures of accuracy in computer classification were determined by establishing several test fields for each training class. The results of accuracy measurements, similar to those discussed for training class performance are presented in the contingency table showing the percent correct identification and the percent commission error at the appropriate thresholds (Table 5). Confusion between evergreen forests and deciduous forests was expected, due to the intermixing of both forest types in the test site.

Areal measurements of the classified ERTS-1 data, totals for the entire test site by number of pixels in each of the six classes plus not classified (thresholded out), are presented in Table 6.

TABLE 6 - TEST SITE AREAL AND PIXEL SUMMARY

CLASS & THRESHOLD	# PIXELS	% TOTAL	SQUARE MILES
Deciduous 15%	2,097	23.8	12.29
Singel Family 30%	6,663	22.4	11.56
Agriculture 30%	5,237	12.5	9.08
Bare Ground 7%	2,929	9.9	5.08
Coniferous 15%	1,296	4.3	2.25
Water 7%	131	0.4	.23
Threshold	6,457	21.7	11.20
Total	29,800	99.9	51.69

Summary: Results of this analysis can be interpreted as promising. A good probability exists that similar experiments in the future will have better results, taking advantage of newer processing techniques, e.g., discriminant analyses using individual pixel grey values for each training class. These are likely to produce more analytical studies of training set selection, their representativeness, and channel selection prior to classification. More accurate selection of training classes and test classes may also be assured with the development of new procedures for digitally merging ground truth data with satellite digital tape data. In this way, training on specific land use types can be precise and the accuracy of classification tested over a substantially larger portion of the site.

Preliminary analyses of ERTS-1 digital image processing for land use mapping have shown that significant inputs can be made with this technique in the demand for information among state, regional, and local land use planners. Maps derived from these data are limited in resolution to the ERTS pixel, approximately 1 acre cells, which can be used through cell averaging or similar techniques to create the coarser resolution of the Maryland automated geographic information system format. By this means, the procedures outlined above suggest strong probability of being used to update the information system. The capabilities of automated analysis can be used outside the information system in a similar manner as image interpretation: e.g., to map land use at a coarse level, to detect land use change, to focus more detailed analyses, and to stratify land cover according to homogeneous units for various analyses, such as ecological units, political units, economic regions, for data collection and the attribution of exogenous data.

Comparisons Between Systems

Remote sensors may be evaluated as sources of land use planning information on the basis of the capabilities that are demonstrated in a particular use. While this may be the logical basis for establishing comparisons, only similar or related sensing systems can be compared fairly. Systems which overlap can be compared somewhat less adequately in the area of overlapping capabilities; it is in the area of the system's optimal performance or main function that comparisons can be made fairly.

Therefore, a comparison of ERTS-1 with other remote sensing systems can only be based on the net value of all types of information obtained from one sensor vis a vis another. Means of quantifying values of abstract qualities, e.g., the value of the periodic and synoptic capabilities of orbiting sensing systems, can only be based on comparing the costs of acquiring data in a particular application where these capabilities are needed. Only in the area of qualities that overlap (and are perhaps inadequate measures of actual performance) can tangible benefits and comparisons be made.

The following analysis compares three remotely sensing systems -- ERTS-1, Skylab EREP, and high-altitude aircraft -- in the performance of one task: the acquisition of land use data for use by land use planners. Table 7 contains the results of each system's performance in obtaining land use information. Accuracy was determined on the basis of the number of sample points on the image that were correctly identified, based on "ground truth" information. Measures of performance are taken from various sources: work within the experiment itself and investigator's experience (EarthSat).

The important distinctions between systems are generally based on differences in resolution: boundary delineation and more accurate identification improves from ERTS-1 through Skylab to high altitude aircraft as resolution changes from 100 meters to 15 to <3. ERTS has limited to no capability in identifying objects at Level III except for those which are large and have distinct characteristics; whereas, both Skylab and high altitude aircraft data provide substantial information at this level (poor performance in Level III (agriculture) and Level II (forestry) is the result of using color rather than color infrared film in Skylab 190-B).

TABLE 7
COMPARATIVE INTERPRETATION ACCURACIES

Land Use Class	Level of Detail	% Correct		
		Aircraft	Skylab	ERTS-1*
Urban	1	100	94.4	90+
	2	95.8	84.7	<80**
	3	94.4	81.9	n.d.
Agriculture	1	98.5	92.6	90+
	2	98.5	92.6	80-85
	3	85.2	51.5	n.d.
Forest	1	97.7	88.5	95+
	2	89.7	17.2	n.d.

* ERTS-1 accuracies based on symposium results;
** incomplete list; no data.

Compensating for the gain in identification accuracy of aircraft over ERTS-1 is a loss in coverage and the frequency of coverage, which could not be duplicated by aircraft except at high cost.

In other words, all three systems permit identification and mapping of all primary, most secondary, and many tertiary land use classes. All systems can be used to stratify the landscape for more detailed sampling, and all can be used to update maps. It is important to realize, however, that differences between systems are a matter of degree. Some tasks can be performed better by one system than another. The above systems are highly distinct and yet highly complementary. Choice between them should rather be based not on one or the other but what combination of systems would achieve the best performance, cost-effectively.

ERTS-1 AND OTHER REMOTE SENSORS IN THE ANALYSIS OF CRITICAL AREAS

Remote sensing technology has been applied in a variety of "critical areas of State planning concern." Each of these studies was in the form of a demonstration project that investigated and evaluated the capability of ERTS and/or high altitude remote sensors and their relative utilities in light of comparative norms, such as cost-effectiveness, accuracy, etc. This section of the report is organized under nine major headings, each devoted to a particular "critical area," the nature of problem(s) examined, and the technology and techniques used to examine the problem. The nine topics are analysis of:

(1) location and classification of coastal marinas

(2) Worcester County shoreline

(3) Deep Creek Lake Area

(4) Baltimore City

(5) Baltimore-Washington corridor

(6) bare ground in the Baltimore-Washington corridor

(7) forest defoliation

(8) geologic fractures

(9) water resouces

These studies present varying mixes and emphasis upon remote sensors, ranging from studies which depend on ERTS as the sole source of information (forest defoliation, geology), to studies partly dependent on ERTS, and to those dependent on remote sensors other than ERTS. Important techniques of analysis which are developed in the course of study are described as they apply to the particular study. Each study and its relevant analytical techniques were reported in the form of Technical Notes to the Department of State Planning during different phases of the investigation. Aside from investigating and evaluating remote sensors in practical use, the study of critical areas sought to develop a basis for projecting costs and technical requirements for extending analyses to larger areas, regional or statewide. For this reason, the design of some studies focused on a sample area; thus, several studies do not represent typical analyses of problems irrespective of their distribution.

Location and Classification of Coastal Marinas

Marinas along the shorelines of the Chesapeake Bay are commercial activities subject to permit and regulatory control. They vary in character and function, often on the basis of associated facilities, and are considered by State planners as an important influence on the character of coastal areas and the use of resources.

A basic inventory was performed from high altitude color infrared aerial photography, acquired on August 22, 1972, which identified the location of coastal marinas in Maryland. Various categories were developed on the basis of associated facilities and the relationship of the marina with the shoreline: dredge channel, jetty, and marinas which combine channel and jetty types. Private docking facilities were not recognized as marinas. The Type II report dated April, 1973, to NASA reports the results and analysis of marinas and examines the ability of the investigators to discriminate known marinas on ERTS imagery.

According to the findings of this study, there are three types of marinas: dredge channel marinas, which are constructed by dredging a channel into shoreline property by the dredge-and-fill process; jetty marinas, which are constructed by erecting jetties as extensions of the shoreline to the marina proper; and, combinations of the two types. Examples are shown in Figure 10. Of the total of 235 marinas identified, 38 were of the dredge channel type, 172 of the jetty type, and 25 combination type facilities. Results compared closely with the records of the State Planning Department. High flight imagery was thus shown to be capable of locating and identifying the nature of all the important marinas. This capability is significant in a regulative program which seeks to minimize the environmental impact caused by marinas which are built haphazardly and without authority.

The technique of location and classification was based largely on August imagery, a period when marinas were typically full of boats and boating activity was prevalent (in contrast to December, when many boats are stored). Marinas are generally not visible on ERTS imagery, except for some large facilities which can be detected (e.g., dredge channel types) because of the extensive excavation and denudation of vegetation that becomes necessary. ERTS, however, does not seem applicable to this type of inventory, and high altitude aircraft may have routine application only when supplemented by a system of records. Regulatory requirements necessitate a high degree of accuracy which ERTS cannot provide, particularly in view of the fact that a resolution of 20 feet or less is often insufficient to distinguish between private and public facilities (the former requires commercial activity permits).

Analysis of Worcester County Shoreline

Planners have devoted increasing attention to the problem of second home development and commercial development attendant to any resource of a recreational nature. A primary example in recent years has been the beach resort at Ocean City and its surrounding area.

Such developments place pressure on delicate resource bases, such as the estuarine ecosystem, as well as demand for urban infrastructures that are difficult to coordinate and plan efficiently. For these reasons, planners have had to respond to land use changes resulting from these developments quickly to mitigate their effects.

Worcester County's northern shoreline, in and around Ocean City, was the test site for this study. High altitude color infrared aerial photography, acquired August 22, 1972, was analyzed to determine the extent and types of residential development in this area. Comparisons were made from the CARETS (1970) land use inventory to assess the degree and character of land use change in the short time period elapsed (2 years). The results and methods of analysis were reported to NASA in a Type II report, dated October, 1973.

Most of the coastal areas appeared to be in the initial stages of "Venice" type developments, characterized by a regular arrangement of landfill strips dissected by dredge channels intersecting a large water body. Extensive wetland dredging and filling was in progress. In most cases channel networks had been dredged and land-fill foundations built up, but construction of dwellings (single-unit detached residences) had not yet been started.

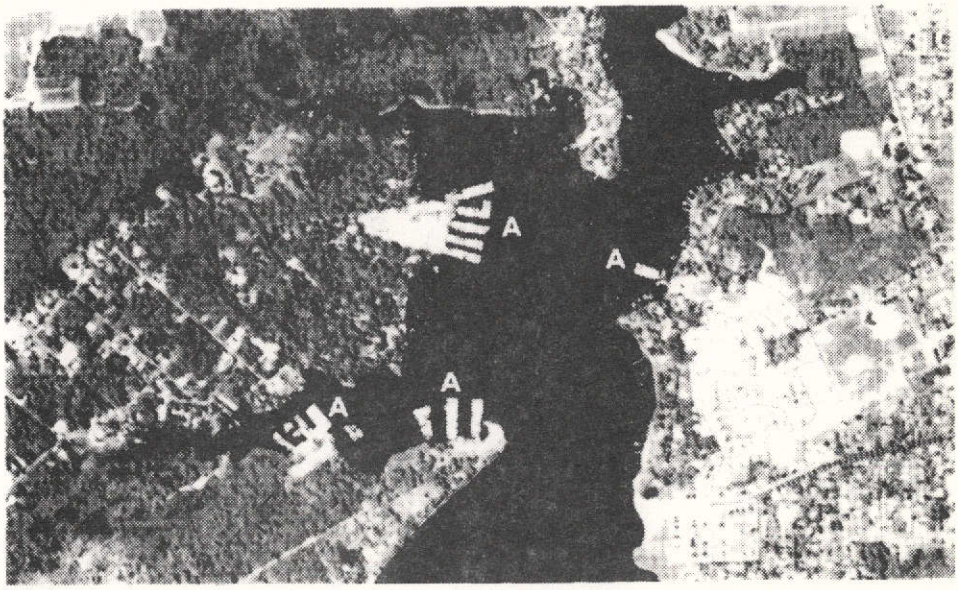
High altitude photography permitted both the type of residential structures and status of development to be observed and inventoried. Such data provide planners with timely information concerning the need for an infrastructure, and with means of monitoring growth and tracking environmental impacts.

Analysis of Deep Creek Reservoir and Vicinity

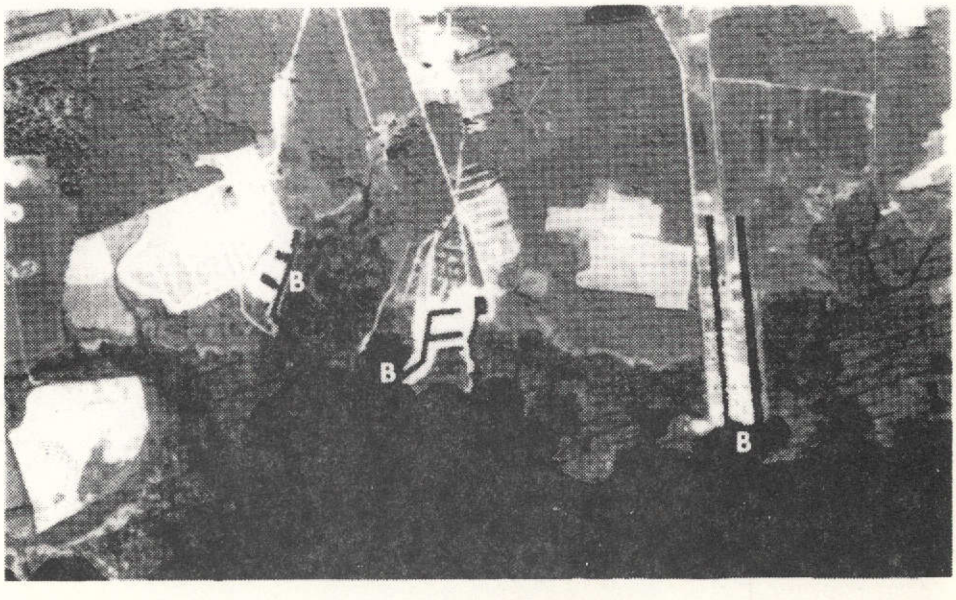
During recent years, the State Planning Department has focused increasing interest on growth and development in non-urban areas. One major source of land use change has been second home and associated recreational facility and commercial development near recreational resources, such as the mountains and lakes. Deep Creek Reservoir, in Garrett County, Maryland, has been the subject of several investigations to determine the extent and type of development, refine existing land use maps, and evaluate various data sources and interpretation techniques that apply to this class of planning problem.

A comprehensive analysis of the Deep Creek Reservoir region was conducted using high altitude aerial photography acquired in January, 1973, magnified from five to twenty times. ERTS imagery was also evaluated in terms of information to satisfy this type of planning requirement. The results of these analyses have been reported in a Type II report to NASA, dated October, 1973. A preliminary land use map was prepared for the area around Deep Creek Reservoir, as shown on Figure 11.

FIGURE 10 - Jetty and Dredge Type Marinas



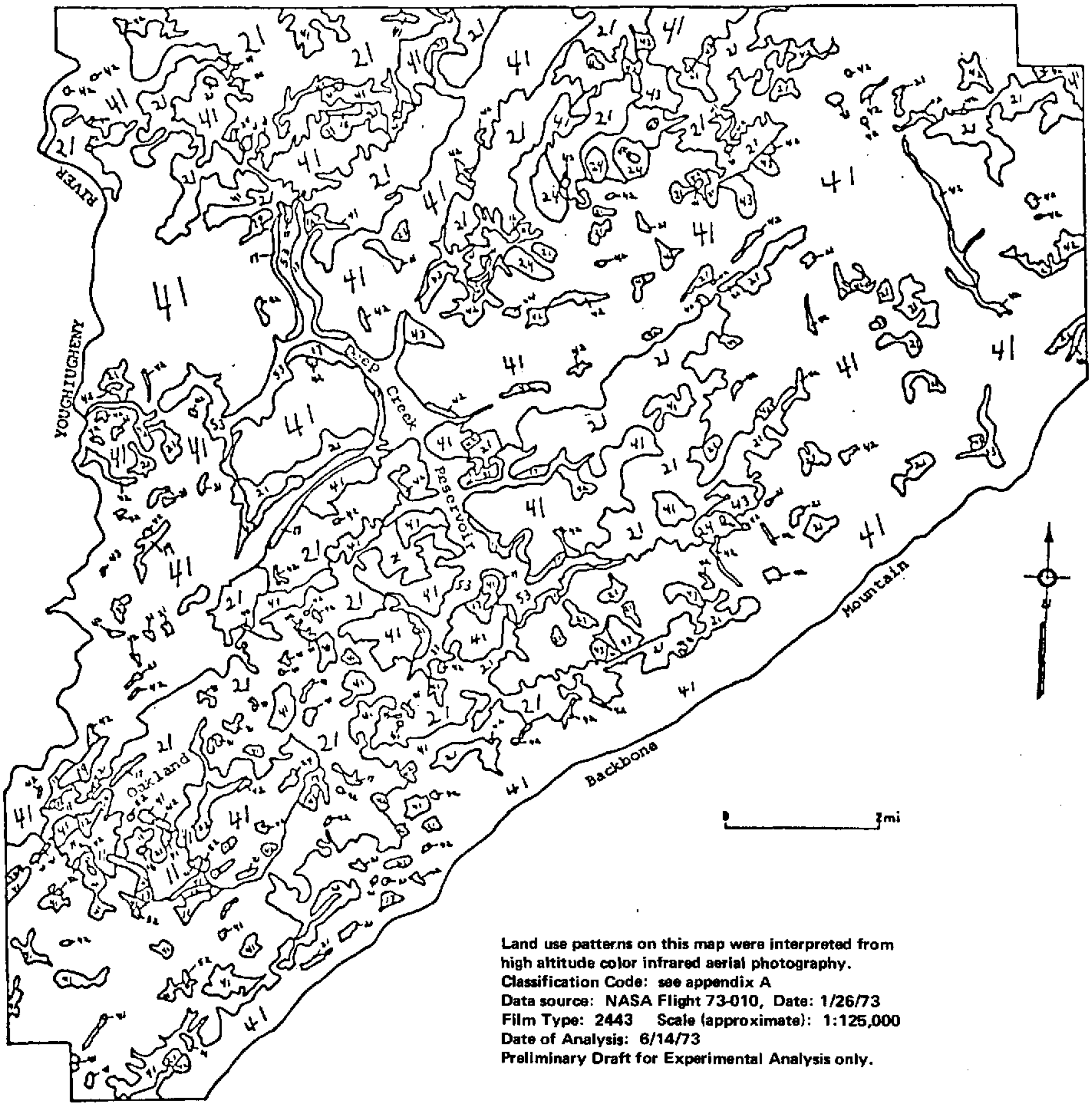
Jetty type marinas are shown at A



Dredge type marinas are shown at B

FIGURE 11

GENERAL LAND USE MAP: DEEP CREEK AND VICINITY – GARRETT COUNTY, MARYLAND



Land use patterns on this map were interpreted from high altitude color infrared aerial photography.
Classification Code: see appendix A
Data source: NASA Flight 73-010, Date: 1/26/73
Film Type: 2443 Scale (approximate): 1:125,000
Date of Analysis: 6/14/73
Preliminary Draft for Experimental Analysis only.

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Data acquired in January 1973 (and other winter months) permitted more information to be extracted from the imagery than was possible using August, 1972 high altitude photography and conventional photo mosaics. A major factor in the ease of interpretation was the presence of snow, which enhanced boundaries of certain features; another was forest phenology, which allowed for separation of major forest species. Information acquired by these means included mixed forest land, abandoned agriculture, ice fracture patterns on the lake surface, and more accurate boundary locations and delineations of development. It readily became apparent that over 70 percent of the shoreline was developed -- significant new information for the planning community.

Accurate records were kept to enable cost comparisons: total interpretation time, for example, to cover a 208 square mile area at 1:125,000 scale was 14 hours (approximately 15 mi.^{2}/hour) plus additional time for editing and analysis.

ERTS images enabled the acquisition of Level I and some Level II data, and were appropriate for information that can be presented at 1:125,000 or smaller scales. High altitude underflight photography provides information at more detailed Levels II and III, and is appropriate for information that must be presented at scales from 1:24,000 to 1:125,000.

Refinement of Land Use Classification in Urban Areas (Baltimore City)

Various studies were conducted early in the project, prior to receiving ERTS-1 data, which were directed toward refining and updating land use information (maps and categories) to determine rates of land use change since the 1970 U.S.G.S. CARETS survey, and to lay a foundation for comparing the information content of high altitude aerial photography, ERTS imagery, and ERTS digital tapes. The main objectives were to assess whether further subdivision of the U.S.G.S. CARETS Level II classification might be made at a finer level, whether enough change was present to warrant more extensive mapping of the State, and to obtain detailed information for small sample areas to compare with ERTS-1 imagery at a later date. The various analyses were conducted for areas in the cities of Bowie, Laurel, Columbia, and Baltimore, Maryland. They are reported separately as studies of Urban Areas (Baltimore City) and Suburban Areas (the remainder).

High altitude (ERTS underflight) RC-10 aerial photography at 1:130,000 scale acquired in August and December, 1972, was available for interpretation. In those instances where a vegetative cover obscured ground data, December imagery proved more useful. Otherwise, visual discrimination among different types of residential patterns is rarely discernable from the imagery. Interpretation of individual dwelling types was conducted with no ground truth assistance. Accurate logs of time were kept as a basis for comparing interpretation time with different systems.

The target area selected in Baltimore City was bounded on the north by the Northern Parkway, on the south by 33rd Street, on the east by

Hillen Avenue-Perring Parkway, and on the west by Charles Street (Figure 12). Examination of the imagery led to the identification of four types of residential land use, which demonstrated that the U.S.G.S./CARETS classification could be refined in Baltimore City with this imagery. The types were: (1) detached single family unit dwellings; (2) multiple family unit developments of duplex and quadraplex structures; (3) apartment complexes; and (4) row houses. Although these types can generally be observed on small scale imagery (1:130,000), it is necessary to map this level of detail at a larger scale (1:63,360 to 1:24,000). An update of the land use patterns did not seem warranted because there were not land use changes detectable between 1970 and 1972.

Refinement of Land Use Classification in Suburban Areas (Bowie, Columbia, and Laurel, Maryland)

A refinement of the land use classification for Bowie did not substantially alter the existing CARETS delineations because the overwhelming majority of residential structures in the city are detached single family unit dwellings. Only two small areas of townhouse developments were found.

An update of land use delineations did, however, seem necessary for Bowie. Of a 130 square mile area around Bowie that was analyzed, approximately 7.3 square miles (5.6%) had a different land usage in 1972 than in 1970. New residential areas accounted for 52 percent of the reclassified area (formerly agriculture). All new development observed on December, 1972 imagery, appeared to be detached single family dwelling units. The direction of future increments of growth was evident: a detached cluster of urban development south of Bowie has expanded on its northerly side, apparently attempting to join the larger cluster of Bowie property; clearing and grading of agricultural land, a process that prepares for urban development, can readily be identified. In other instances, however, it was difficult to separate recently plowed areas from those readied for development. What constitutes fallow, idle, and pasture land is often difficult to classify as well as to identify. While these activities can be identified, attributing the purpose of the activity may in all probability require monitoring the phenomenon.

Refined land use data for Columbia would have been useful for planning purposes. However, discrimination between types of multiple family housing is difficult on 1:130,000 scale imagery, and for this reason, all such housing was classified as one type.

Over a 100 square mile area in and around Columbia was examined in this study. The eastern sections of the region show residential growth on land formerly open or in agricultural use (cropland). Only 1.8 square miles, however, had changed from 1970-72, 36 percent changed to residential land use, and 27 percent changed to commercial use (Figure 13).

Residential land use can be sub-classified in Laurel from both August and December RC-10 imagery. Among the types observed are: (1) offset quadraplex townhouses, (2) duplex townhouse clusters, (3) apartment complexes, (4) multiple family units of undetermined types, and (5) trailer courts.

A few parcels, formerly classified as open land, were converted to residential use; consequently, a need for map updating was not justified.

There is no doubt that high altitude aerial photography provides sufficient information to update previous land use maps by at least one level, e.g., Level II to Level III, and permits accurate map updating and change analyses. The ability to find detailed information, however, must be matched with an ability to use and depict this information. Types of land use at Level III generally contain small parcels that cannot be depicted graphically, such as on a map, unless that map is substantially larger in scale than the scale of the information source. Consequently, it has been determined that Level III information is more compatible with map scales in excess of 1:63,360 scale, e.g., where one inch equals less than one mile.

Due to the level of detail represented, times to interpret each sample area vary substantially, particularly on an areal unit basis. In Bowie, for example, only three hours were required to map 130 square miles because the number of areas of detailed land uses were few and highly concentrated; Columbia, with 100 square miles, took five hours to interpret; Laurel required six hours, primarily because residential land uses were highly varied and intermixed; and, in Baltimore, where only 86 square miles were examined, six hours were required to map the urban complexities. If more specific determination of residential development types was necessary, time for field checking interpretations would escalate proportionate to interpretation time; for this reason, both considerations should be treated in an appropriate interpretation program.

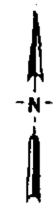
<u>ERTS Data Applications</u>: Many details in urban and suburban landscapes such as small parcels of a discrete land use class and the characteristics of residential land uses which create sub-classes are too fine to be observed on ERTS images. More noticeable, however, are changes which occur in the natural landscape seasonally and, in the urban landscape, with growth and development. Having this capability, ERTS data can be used to define areas where detailed information must be obtained to update existing maps.

Photo density slicing and digital analysis techniques were employed in the three suburban test sites with limited results. Density slicing of ERTS-1 data were tested for mapping residential land use patterns using Agfacontour film and an additive color viewer and manual interpretation techniques. Density slices were taken from two separate transparencies, MSS Bands 5 and 7. The results of this analysis indicate that some of the same problems of manual interpretation methods reappeared:

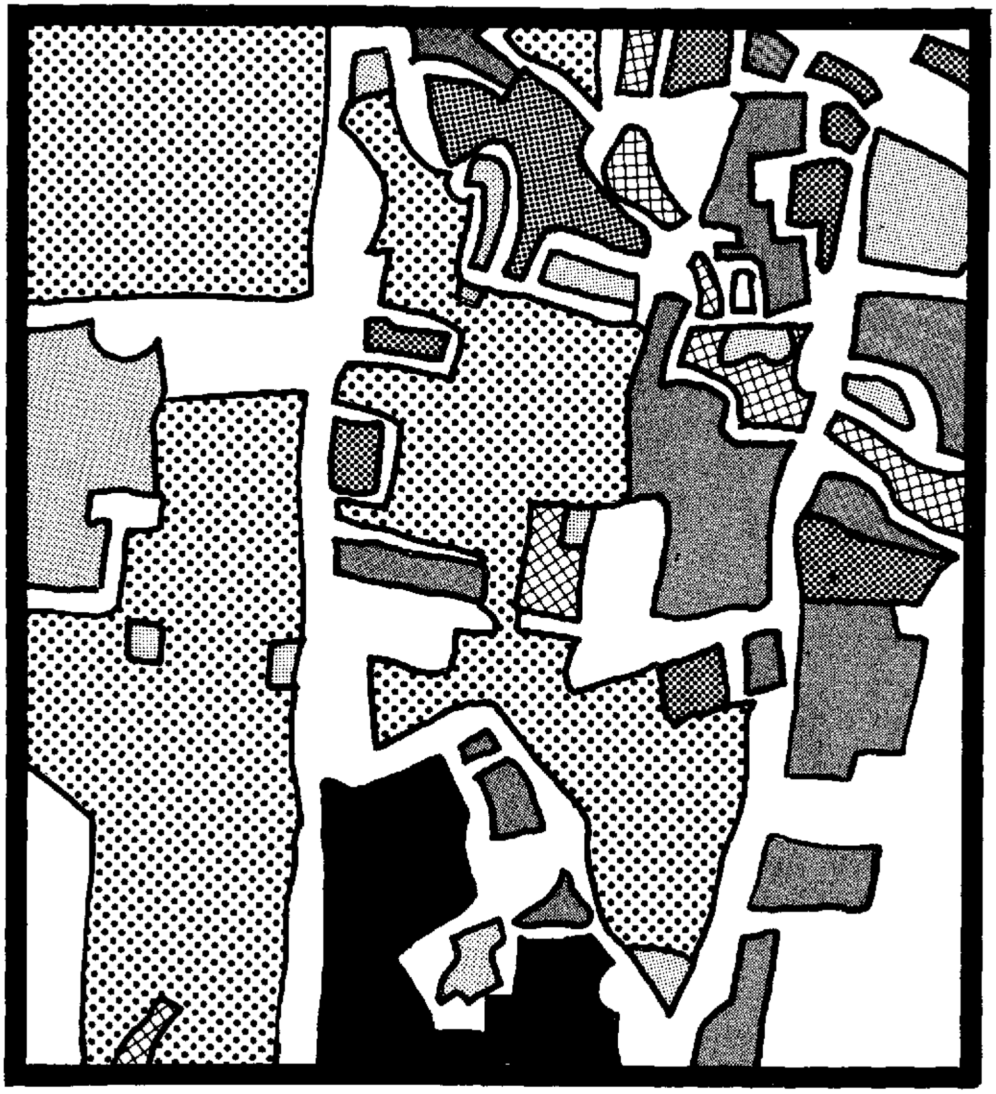
FIGURE 12

NORTH BALTIMORE CITY, 1972

RESIDENTIAL AREAS



1:26,0



LEGEND

Parks

Schools, Hospitals

Single Family Residential

Multiple Unit Residential

Apartment Complex

Row Houses

Uninterpreted

LAND USE CHANGE—COLUMBIA AND VICINITY

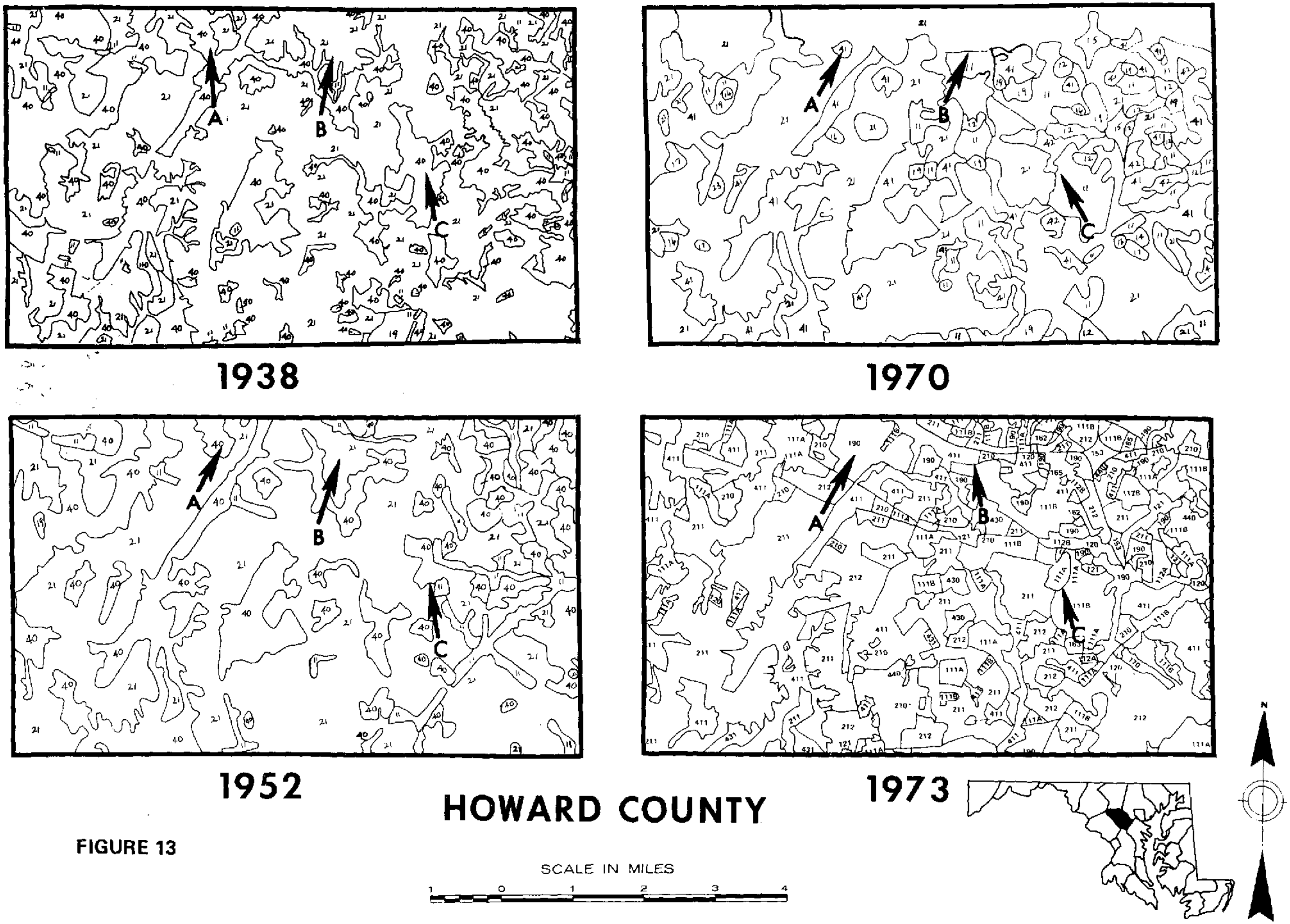


FIGURE 13

agriculture could not always be separated from urban and built-up land on winter images (chosen to eliminate deciduous tree canopies). By trial-and-error, a filter and light intensity combination was arrived at on the additive color combiner that best represented the actual distribution of residential areas. In this way, single theme image maps were prepared for Rockville and Bowie, Maryland, and compared with detailed land use maps. In Bowie, where land use patterns were reasonably homogeneous (i.e., similar over large areas, not mixed), residential areas were separated from commercial areas, parks, and tree covered areas, as shown in Figure 14. No separation could be obtained, however, between residential areas and fallow agriculture. The results of this experiment indicate that the distribution of features with spectral characteristics occupying a narrow region can be identified with photo density slicing techniques, but that the features so identified have other characteristics spectrally unrelated which form different classifications. In other words, the technique has the advantage of photographically identifying the distribution of all features whose spectral characteristics are similar; this allows the image map to be enlarged and data to be transferred to virtually any scale of base map. Whether spectral similarity is useful information by itself or as a surrogate for other information has not been determined.

The other technique, digital analysis, employed the LARS maximum probability classification method and several statistical evaluation techniques. By emphasizing patterns formed by pixels, rather than the objects themselves, patterns of residential areas, shopping centers, parking lots and surrounding wooded areas were identified on October, 1972 data, again, in the Bowie test site. These data were evaluated at map scales as large as 1:26,000.

<u>Analysis of Bare Ground in the Baltimore-Washington Corridor</u>

Planners generally concur that if they had the ability to identify areas where ground has been laid bare, i.e., cleared of cover such as when land is prepared for urban development, they might have a means of policing land use change and monitoring its rate and direction. Erosion reduction and runoff water quality maintenance are two benefits that could be derived from using such data.

The corridor between Baltimore and Washington is an active area of urban and industrial development which contains a large amount of non-argicultural and agricultural (fallow or bare due to season and crop rotation) bare ground. Non-agricultural bare areas typically result from land subdivision, mining of sands, gravels, and clays for use in the construction process, and from being unsuited to either agriculture or urban purposes, e.g., rock outcrops.

Since bare ground is an anomaly in a humid region where most land is vegetated or built-up, the spectral signature of bare bround may be interpreted as land which has been disturbed. It was thus assumed that identification techniques based on spectral information would produce information on the urban growth process, i.e., bare ground as a precursor of construction. Both the direction and rate of growth could be determined from data that are periodically obtained from a system such as ERTS. A combination of both digital and photographic techniques appropriate to ERTS data were used and compared. Results generally indicate the relative merits of each technique and recommend directions for future research. The following analysis examines the results of these techniques.

A study of dynamic phenomena requires that both sets of data, the initial set from which information is derived and the set which corroborates observations taken from the first, be obtained at approximately the same time. In this experiment, data were obtained 24 days apart: July 8, 1973 for the ERTS data, and June 14, 1973 for the high-flight photography used for corroboration. The test site chosen for this analysis (Figure 15), measured 3.5 miles by 14.5 miles (approximately 51 square miles), a 100 by 300 pixel area of the Baltimore-Washington corridor. Within this area are: the eastern portion of the city of Columbia including its industrial park; commercial centers at Beltsville, Laurel, and Columbia, Maryland; agriculture at the Beltsville Agricultural Research Center; and sand and gravel extraction areas.

Ground truth for this experiment consisted of a land use map developed from the June 14, 1973 high-flight imagery. The results of each analytical technique were compared with the ground truth map and instances of correct identification and errors of omission and commission were identified. The ground truth map was designed to interface with the 1973 Maryland Land Use Inventory. For purposes of this study, no area smaller than 10 acres was recognized. The categories included: Open and Bare Ground, Residential Construction (single family units, multiple family units), Industrial Construction, Quarries, and Sand and Gravel Pits.

Both enhancement techniques (photographic and digital) and digital analysis techniques were used for monitoring bare ground. The various techniques were:

(1) the LARS Maximum Likelihood Multispectral Classification System;

(2) Multispectral Digital Image Analysis System (Image 100);

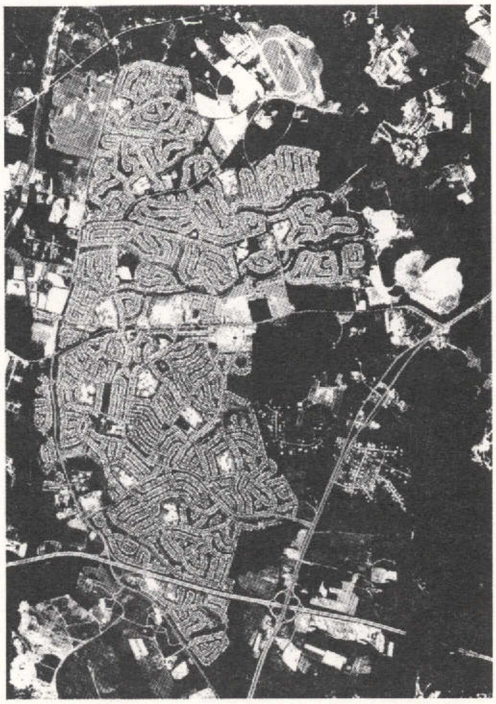
(3) Digitally enhanced photographic prints;

(4) Digital color analyzer; and

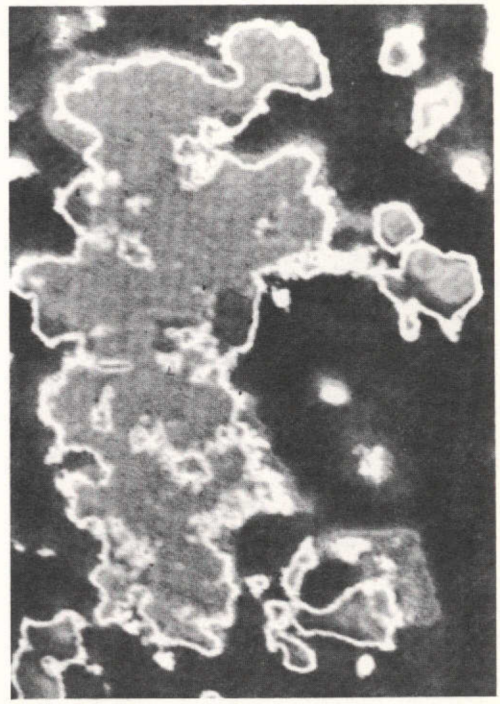
(5) Photographic density slicing.

FIGURE 14 - Residential Land Use ERTS Density Slice in Bowie, Maryland

Comparison of "ground truth" aerial photograph at A ,
ERTS density slice at B, and interpreted map at C.



A



B

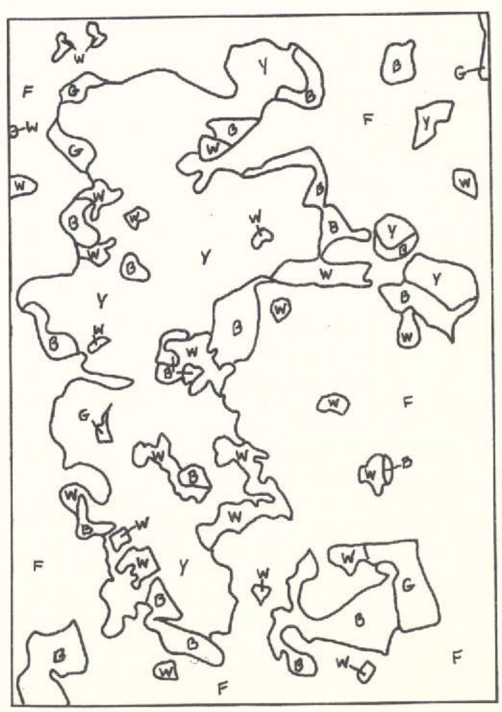
Y = Single Family Residential

B = High Intensity Urban Infrastructure or Bare Agriculture

W = Low Intensity Infrastructure or Residential/Infrastructure Fringe Zone

G = Vegetative Cover Present (Golf Course or Winter Agriculture Crops)

F = Forest or Dormant Agriculture



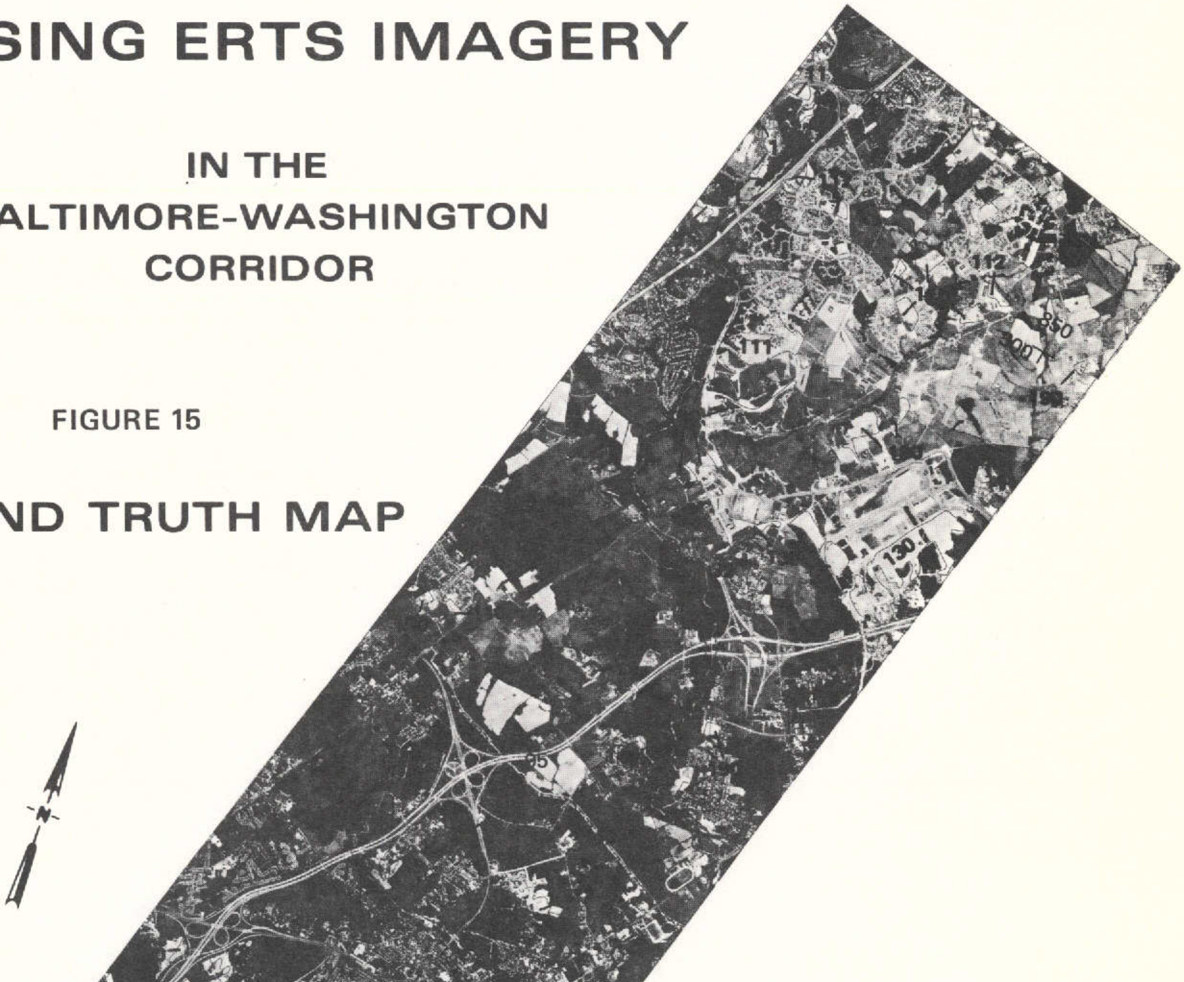
C

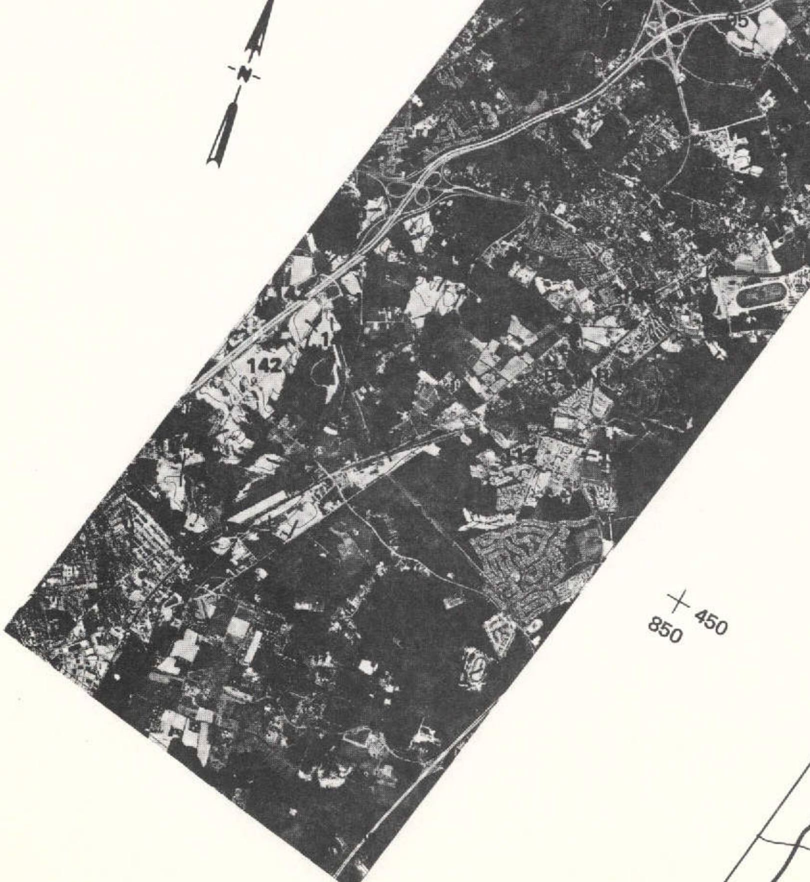
DETECTION OF BARE GROUND USING ERTS IMAGERY

IN THE BALTIMORE-WASHINGTON CORRIDOR

FIGURE 15

GROUND TRUTH MAP

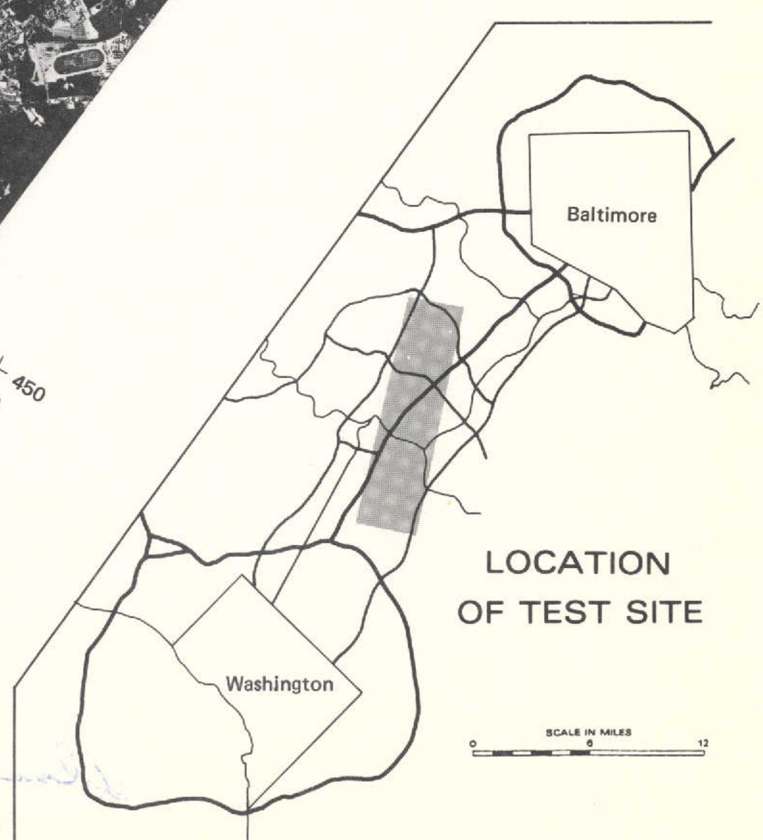




450
850

SCALE IN MILES

1 0 1 2 3 4



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The results of these systems comparison are presented in Table 8. The discussion that follows treats each system in order of its ability to identify bare ground; errors of omission and commission will be discussed simultaneously. Problems encountered through the use of data from separate dates (e.g., "ground truth" dated June 14, 1973, versus ERTS-1 data dated July 8, 1973), will be discussed at the end of this section.

Table 8: Identification of bare ground using various enhancement/identification procedures

System	% Correct Identification	% Errors of Omission	% Errors of Commission
LARS Maximum	80	20	240
Likelihood	80	20	240
GE Image 100	75	25	120
Digitally Enhanced Photo	70	30	150
Digital Color Analyzer	45	55	50
Photo Density Slicing	35	65	40

The LARS Maximum Likelihood System: This system calculates the probability that a pixel belongs to a specific class of objects with a defined set of spectral characteristics, and assigns pixels to the class with the highest probability. A user may also define the minimum probability and exclude all pixels less than this threshold value.

The signature of the bare ground training class was distinct relative to other land use classes. Internal variations in the signature were considerable, but these could be attributed to the differential reflection of soils in the bare areas as well as its roughness. Applying the LARS system to the data produced a classification (Figure 16) that included 80 percent of the bare ground areas in the Baltimore-Washington corridor, and three times as much area that was incorrectly identified. Whereas all the bare ground areas except a quarry (which had spectral characteristics similar to asphalt) were classified correctly, large amounts of concrete highway and roof top signatures could not be separated from the signature within the present scope of analysis, suggesting poor selection of initial training sites, coupled with the prevailing light signatures of leached and eroded soils of the Baltimore-Washington corridor.

Multispectral Digital Image Analysis: Multispectral Digital Image Analysis was performed on the General Electric Image 100 system housed in Daytona Beach, Florida. The system accepts both photographic and

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digital tape data, displaying it in conventional image format on a cathode ray tube (CRT). Its primary function is for interactive multispectral classification. A user selects the elements of a scene for analysis. Training pixels from the areas designated are then queried in all spectral bands to generate signatures that, in turn, are matched against other scene pixels for classification. The number of pixels that match a given scene lineament constitute a theme, which is then displayed with a color code superimposed on the CRT screen and stored in a computer data disk. With this system, training, test, classification, and storage all take a minimum of time; hence, the operator can monitor results, retrain, and recall various themes immediately.

The multispectral digital image analysis system (Figure 17) identified fewer areas than the previous system, but did this with fewer misclassifications. Areas misclassified were basically of the same type as earlier: concrete pavement and roof tops, such as the broad surfaces which occur in contemporary industrial buildings.

Digitally Enhanced Photographic Prints: Digital enhancement of photography is a procedure that uses a histogram equalization program to define a non-linear grey scale adjustment that produces optimal contrast within the image, i.e., maximum differentiation between grey values. Digital enhancement offers the advantage of retraining maximum information content while allowing the user to focus on the MSS data relevant to the topic.

A digitally enhanced photographic print was prepared using a histogram equalization of the MSS Band 5 data. The final print used for interpretation was an enlargement at a scale of approximately 1:120,000. Areas imaged in white on the grey scale enhancement were interpreted as bare ground.

The results of applying this system (Figure 18) were inferior to the previous system both in terms of the accuracy of identifying bare ground (70%), and in terms of the number of misclassifications (150%). Concrete and roof top surfaces again appeared in the misclassified areas.

Digital Color Analysis: The I^2S Digicol image processing system used in this experiment divides image grey scale values from a film positive into discrete color values and generates a false color enhancement display. The system consists of a vidicon camera which views transparent images, generates a signal, and sends the signal to the Digital Image Processor. There, the video signal is separated into equal increments and assigned a color signal to be displayed on a monitor.

A nine inch positive of MSS Band 5 was found to offer the best discrimination of bare ground among the four bands. Training focused on known bare ground with particular attention to the elimination of highways which are close to bare ground in spectral signature.

DETECTION OF BARE GROUND USING ERTS IMAGERY

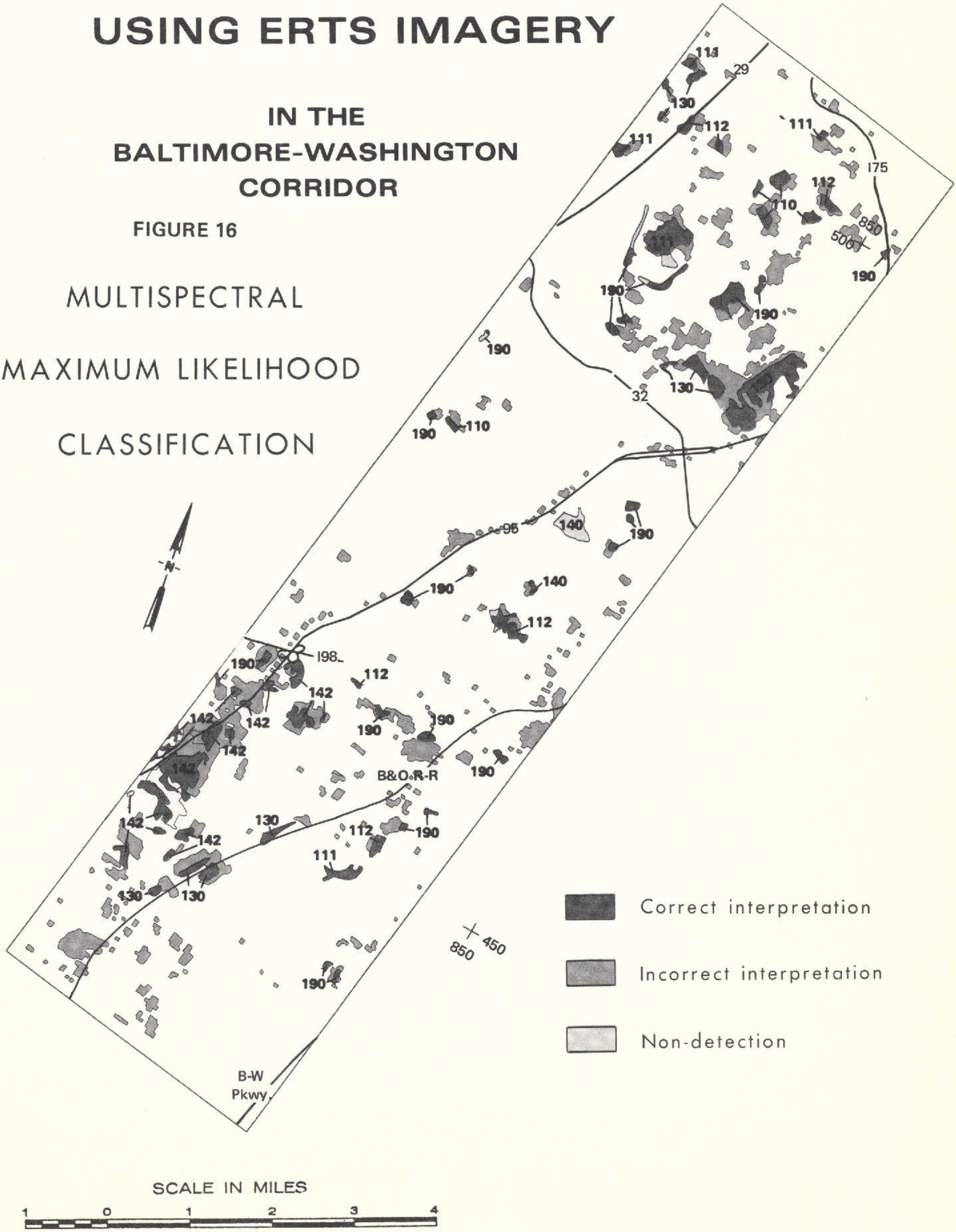
IN THE BALTIMORE-WASHINGTON CORRIDOR

FIGURE 16

MULTISPECTRAL

MAXIMUM LIKELIHOOD

CLASSIFICATION



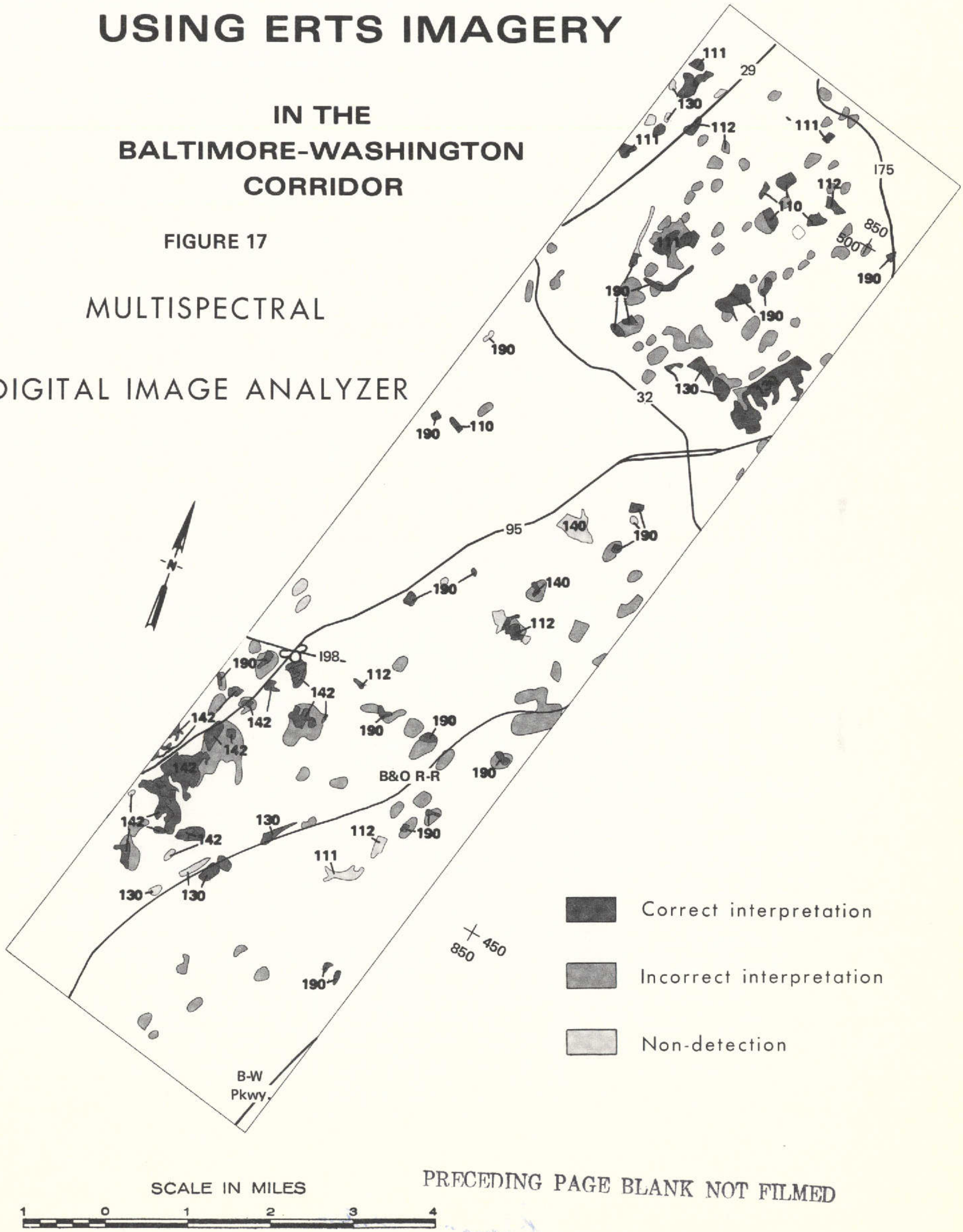
DETECTION OF BARE GROUND USING ERTS IMAGERY

IN THE BALTIMORE-WASHINGTON CORRIDOR

FIGURE 17

MULTISPECTRAL

DIGITAL IMAGE ANALYZER



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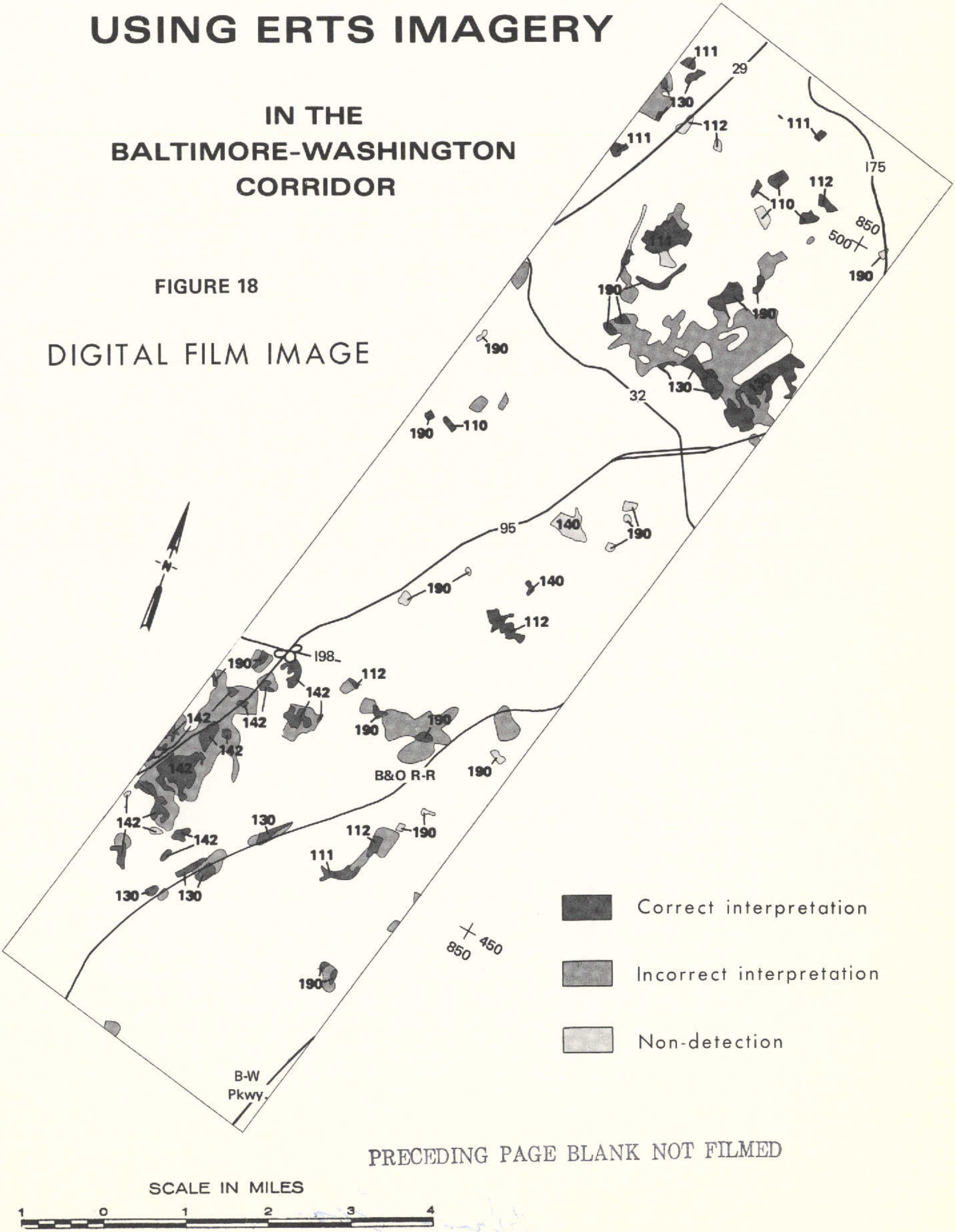
DETECTION OF BARE GROUND USING ERTS IMAGERY

IN THE BALTIMORE-WASHINGTON CORRIDOR

FIGURE 18

DIGITAL FILM IMAGE



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Results from this system (Figure 19) show that less than half the area was identified, and slightly more than an equal amount of new area was misclassified. Misclassifications remained a mixture of both concrete highways and roof tops. The accuracy of this technique was low primarily due to system resolution degradation that results when information is transferred from bulk MSS data to film, from film to the vidicon camera imaging system, and from the imaging system to the color monitor. In all probability, difficulties in data transfer are less likely to be resolved than some of the problems of redefining spectral signatures and establishing better training sets.

Photographic Density Slicing: The technique of density slicing, previously discussed, uses Agfacontour equidensity film to isolate areas of photographic density through primary and secondary density slicing. Manual interpretation methods are then employed to a number of specific features, map areas, etc. Proper application of the technique relies on a skilled photographic technician and the proper isodensity film (a German film, not actively marketed in the United States). Whereas total cost may be low, application of the technique may otherwise be difficult to implement.

The results of bare ground analysis by density slicing demonstrated the least capability to identify bare ground, but also the least ability to misclassify other areas (concrete and roof tops).

Analysis of experiment: The five analytical tools applied to a study of bare ground in the Baltimore-Washington corridor demonstrate that the spectral characteristics of bare ground are not distinct relative to concrete and several types of roof materials used on industrial buildings, and that however the spectral signature is defined, misclassifications cannot be eliminated without severely attenuating the area of bare ground identified.

Results of this experiment must be considered incomplete, but very encouraging for further research and development. Further refinement of the training sets and engineering, and better identification of the appropriate grey scale level in the one-dimensional techniques may lead to improved results with each of the systems. Despite the fact that present analysis techniques cannot reduce errors of commission, the capability of several techniques, particularly Image 100 and the LARSYS techniques, are most encouraging. If the objective is to identify particular features for the purpose of monitoring them and applying certain regulations, the two techniques have some demonstrated capability. Both can separate bare ground, concrete and roof tops from all other features and perform this task in a minimum of time, meanwhile identifying 75 percent or more of the bare ground in the region. A monitoring system could be set up by identifying all features classified and misclassified on one image through "ground truth" information and then periodically observing changes in the total inventory. Bare ground areas, being ephemeral phenomena, should appear and disappear; concrete and roof tops would reappear on each image.

The most important requirement of a monitoring system would be to have adequate confirmation or "ground truth" data for the base period used to reference subsequent inventories. Lack of such data in the present experiment (high-altitude imagery flown on June 14; ERTS data acquired on July 8, 1973), undoubtedly influenced the results. Bare ground on the June 14 image may have been occupied by July 8 and therefore could have been classified as an apparent omission error; new bare ground on the July 8 image would appear as a commission error with reference to the "ground truth" data which would not record this feature.

Analysis of Forestry and Forest Defoliation

The State planning community maintains a continuing interest in accurate, current inventories of natural resources, including forest lands, for effective environmental and general comprehensive land use planning requirements. In Worcester County, for example, several forested areas have been proposed as Conservation Areas or Limited Use Areas in the Maryland Outdoor Recreation and Open Space Plan. Several areas such as Oak and Sassafras Hammocks and the Pocomoke River Swamp, have been designated unique natural areas.

Worcester County is located in the east-central portion of the Delmarva Peninsula. Three of its sides form state boundaries: Delaware to the north, Virginia to the south, and the Atlantic Ocean to the east. The County comprises the eastern portion of the Lower Eastern Shore Planning Region. Other than a few, relatively small towns (e.g., Pocomoke City, Snow Hill, and Berlin) and coastal developments near Ocean City, the County's landscape is predominantly a mixture of agriculture, forest, and coastal wetlands. The forests of the County are considered representative of forests on the Delmarva Peninsula.

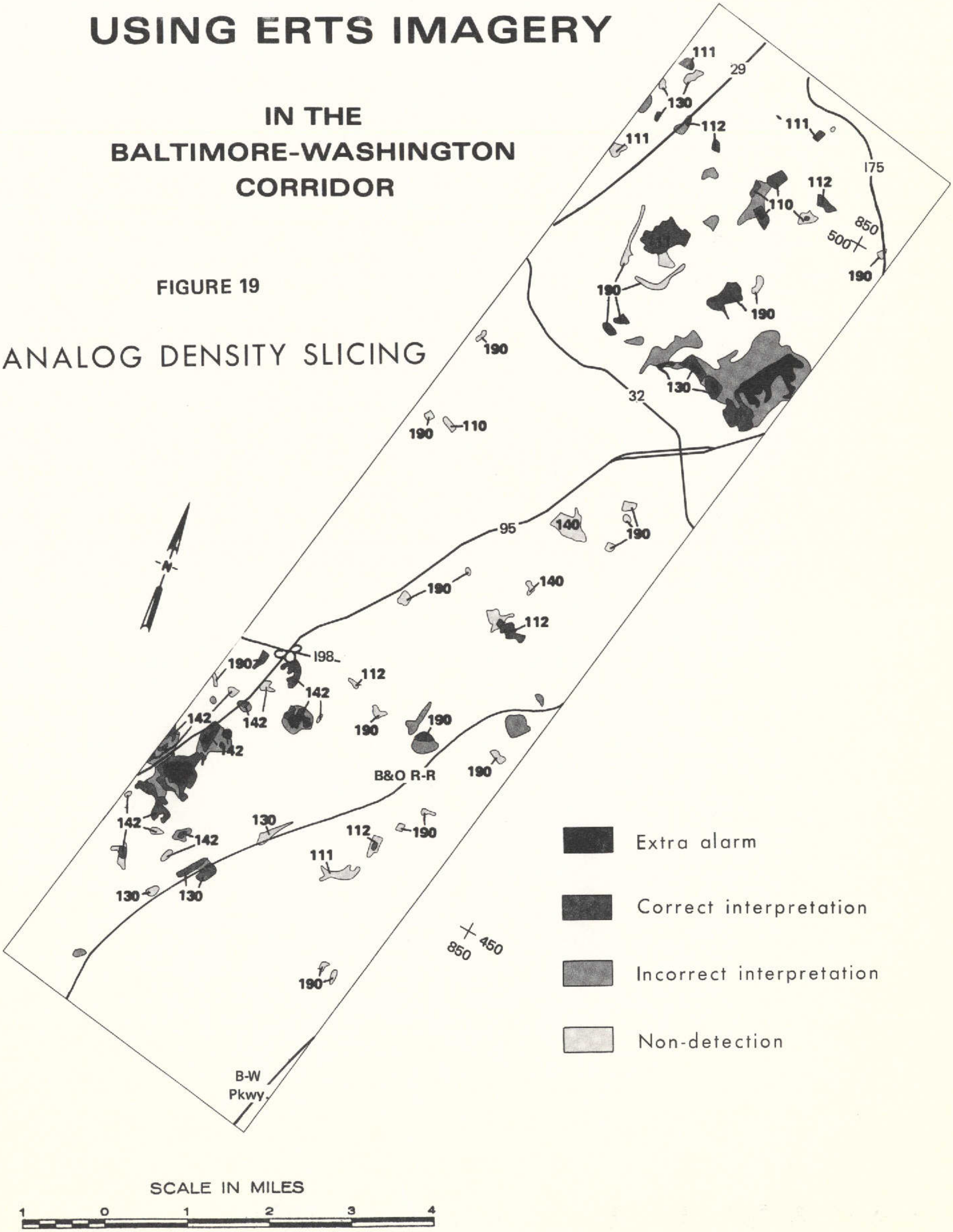
The following analysis demonstrates the application of ERTS-1 data for providing forest resource information to the State planning community. Both ERTS-1 and high altitude aerial imagery were analyzed, interpreted, and used to delineate and evaluate the distribution of vegetation in Worcester County. ERTS-1 analysis was made from black and white multi-band, multi-date images of several enlargement scales (seasonal coverage), and multi-date color composites of multi-band imagery. High altitude infrared ektachrome aerial photography was interpreted to provide "ground truth" data for subsequent comparison with the ERTS-derived vegetation map and to provide a basis for interpreter training.

DETECTION OF BARE GROUND USING ERTS IMAGERY

IN THE BALTIMORE-WASHINGTON CORRIDOR

FIGURE 19

ANALOG DENSITY SLICING



High altitude aerial photography acquired on January 26 and 31, 1973, was interpreted for general vegetation categories and boundaries. Overlays made of this information were compiled to an uncontrolled base and a general vegetation map was produced at approximately 1:130,000 scale (Figure 20).

ERTS imagery selected for two seasons, October 10, 1972 and January 26, 1973 maximized the information that could be obtained from phenological change as an aid to interpretation. General vegetation categories and boundaries were interpreted and delineated on overlays to black and white photographic enlargements of MSS Bands 5 and 7 for each date, at 1:250,000 scale.

Forest land is relatively easy to differentiate from all other landscapes. Deciduous stands are often difficult to separate from coniferous stands, particularly in areas of mixed stands. Homogeneous stands create consistently unique and identifiable tone/texture patterns which can be identified easily.

Boundaries in coastal areas were difficult to delineate due to tidal fluctuations which cause variations in water penetration. It was also difficult in coastal areas to differentiate coniferous vegetation from species common to wetlands. Riparian vegetation particularly the cupress communities, produced a spectral signature that was neither typical of coniferous or deciduous vegetation. Further analysis is needed of this unique signature and the factors which create it.

Comparisons of the high altitude-derived "ground truth" vegetation map and the ERTS-based vegetation map indicate general agreement on the data and interpretations. ERTS has a definite advantage as a data source; aerial photographic interpretation required 28 hours, map preparation, editing, and analysis took 22 hours; ERTS-1 interpretation required 15 hours, map preparation, editing, and analysis took only 12 hours. Color combined imagery was used primarily for "quick look" analyses. The utility of this type of imagery was not fully explored.

Analysis of forest defoliation: An analysis was made to evaluate the applications and limitations of ERTS-1 data for detecting and mapping forest defoliation. Extensive forest defoliation occurred in a portion of Frederick County, Maryland, during late May and early June, 1973 as a result of fall cankerworm (*Alsophila pomentaris*). Although the insect rarely causes extensive mortality among trees it affects, defoliation can cause reduced growth, increase the susceptibility of the stand to other insects, and create an aesthetically unpleasing site. Ability to detect and identify the area of defoliation is important to State agencies of Maryland which are responsible for forest management. This information would enable them to implement suppression procedures in a more timely manner.

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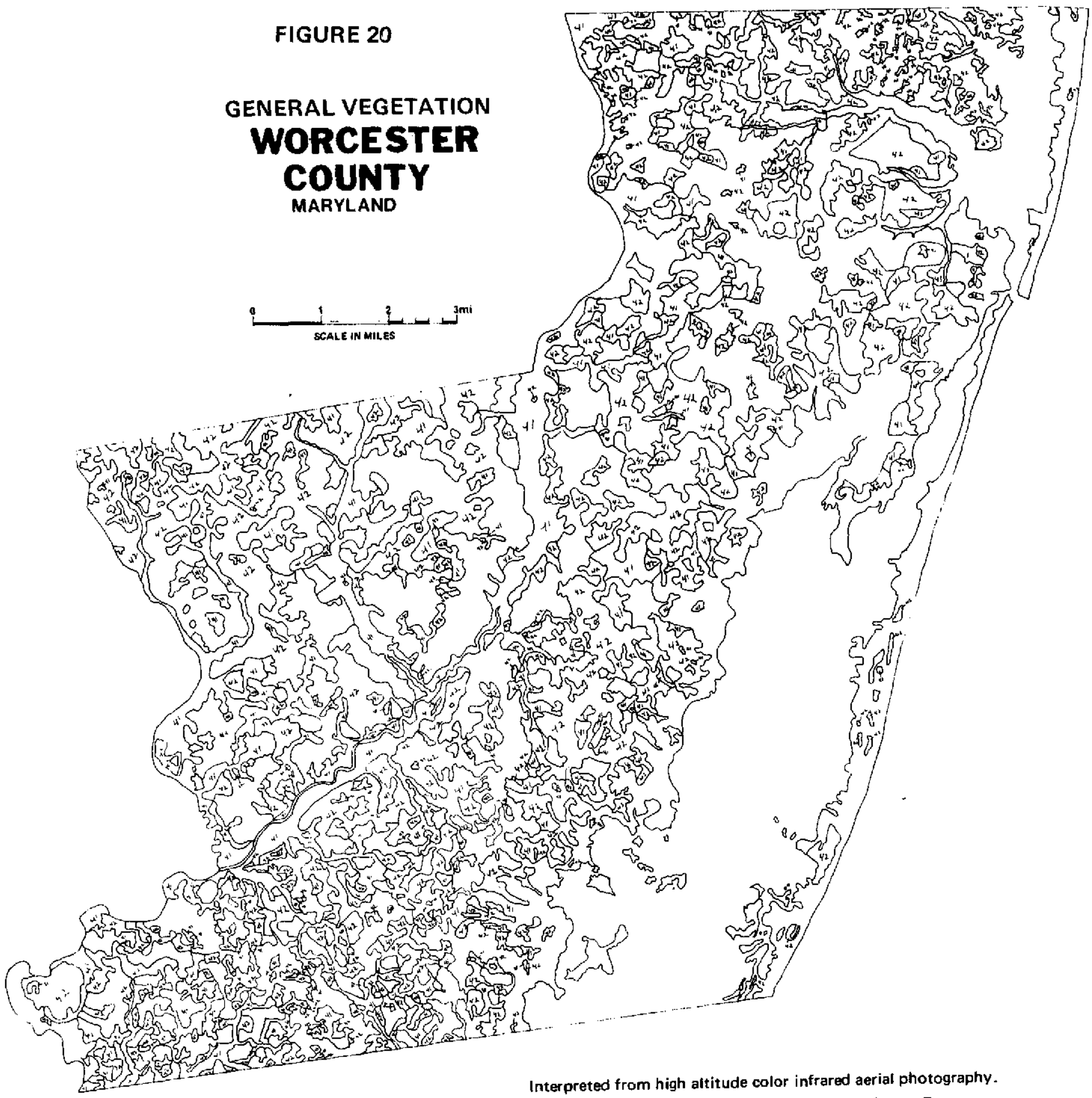
FIGURE 20

GENERAL VEGETATION

WORCESTER COUNTY

MARYLAND



Interpreted from high altitude color infrared aerial photography.

Classification Code: 41= Deciduous, 42= Coniferous Forest.

Data Source: NASA Flight 73-014C, Date: 1/31/73
73-010 1/26/73

Film Type: 2443 Scale (approximate) : 1:130,000

Date of Analysis: 6/14/73

ERTS-1 imagery acquired on June 2, 1973 was used in this analysis. Black and white transparencies of Bands 5 and 7 were used to prepare various single and multi-date color composites. All imagery was subsequently analyzed by human interpreters. Defoliation imaged as light tone on MSS Band 5 and as a dark tone on MSS Band 7 (Figure 21). The defoliation was clearly visible on RC-10 color infrared photography flown the previous day (June 2) and twelve days later (June 14). By June 20, when the subsequent ERTS pass occurred, clouds obscured the site; and, by July 8, when the next opportunity for observation arose, the damaged trees had become refoliated.

The ability to detect defoliation from single bands of ERTS imagery depends on its intensity. Heavy defoliation can be identified, but medium and light defoliation are most readily identified only when adjacent to heavy defoliation. Better results were obtained from single date false color composites of MSS Bands 5 and 7, but in both instances, black and white and color, areas of defoliation were often confused with dark toned areas associated with certain agricultural areas. A multi-date false color composite image, e.g., superimposing Band 7 from two different dates as two different colors (red and green) would provide enhancement of defoliation and separation from the agricultural lands.

Detection and mapping of light to moderate levels of defoliation was possible only on the basis of an association with heavily defoliated areas. Increased resolution and/or analysis of the digital tapes could, perhaps, improve this ability.

Users of this information need, however, to have defoliation levels defined, measured, and to have the distribution evaluated. The ability to extract this information from ERTS-1 data, particularly for mixed forests, has not been demonstrated. Until improved capabilities are demonstrated in these areas, the most promising application of ERTS-1 imagery in insect defoliation surveys will be in the preparation of maps depicting the areal extent of heavy defoliation in areas with heavy deciduous forest cover. Timely receipt of the information can be used to focus on priority areas for more detailed analysis. Data would be useful if it were provided within 24 to 48 hours of imaging.

Timeliness with regard to overflight is another important requirement that the present system cannot meet with reliability. Forests attacked by spring defoliators will often refoliate, and if the area is cloud-covered on subsequent ERTS-1 overpasses, the damage may go unnoticed. An ideal system recognizing this limitation, would involve more frequent coverage. In other words, the damage/recovery cycle is of sufficiently short duration that for a satellite system to be useful, it must monitor more frequently as well as deliver the data to interpreters more quickly than it can at the present time. Furthermore, the present system is limited to incidents with a large areal extent. Improved resolution may not only permit identification of levels of defoliation but also identify smaller areas that have been defoliated.

Analysis of Geologic Features

A thorough knowledge of the geology of the land is important both in regional and city planning. Geologic factors, including deposits of minerals, must be considered to properly build, allocate land use, and to minimize geologic hazards. Too many incidents of construction on unsuitable soils, unstable slopes, in floodplains, or in areas of seismic risk have resulted in high human and economic cost. Important mineral resources, their access and development, must also be considered part of any comprehensive plan. Other areas where geologic data play a major role include solid waste management, water resource management (including both ground water and surface reservoir planning), and flood hazards prediction, stream sedimentation, suspended load prediction, source monitoring, and in prediction of potential excavation and foundation problems. Table 9 compares data essential for environmental and land use planning with types of information ERTS imagery can provide.

A recent project by the Maryland Geologic Survey was initiated to prepare a series of interpretative maps for the Baltimore-Washington urban area which present standard geological data in various formats easily understandable by engineers, planners, and builders. This series of maps includes geology, general construction conditions, septic tank conditions, mineral resources, and ground-water resources. The construction conditions map contains nine categories of surface material terrain which are related to excavation and foundation limitations, slope, flood hazard, and compaction depth to water table. The septic tank conditions map indicates areas of potential problems for sewage filtration based on the same geologic features as the earlier map. The mineral resources map contains the location of minerals used in construction: sand, gravel, and ceramic clay. The ground water resources map summarizes data for all important acquifers in the area. Such maps are important basic data for land use planning, especially when combined with a means of updating land use activities in relation to the topics covered by the maps.

The synoptic and repetitive nature of ERTS imagery makes it an ideal source for certain types of geologic data. These include lineament mapping for structural geology studies and ground water development, sedimentation and suspended load data for major drainage ways and coastal areas, and mineral extraction data to delineate the areal extent and change of gravel pits, quarries, and strip mines.

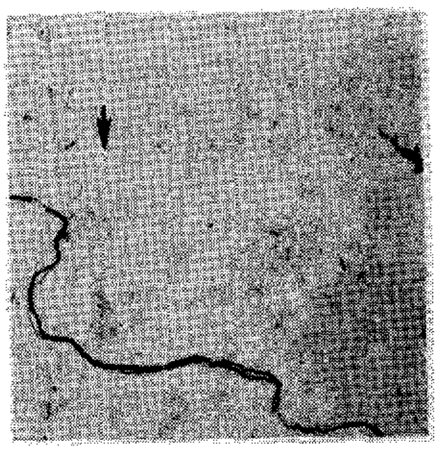
A preliminary ERTS Lineament Map of Maryland, showing major linear geologic features, was prepared by Earth Satellite Corporation (Figure 22). Lineaments were mapped both from black and white (MSS Bands 5 and 7) and color composite imagery (MSS Bands 4, 5, and 7) for several cloud-free overpasses. The final map was prepared as an overlay to accompany the Maryland ERTS mosaic (1:500,000 scale). Three types of lineaments were mapped:

FIGURE 21

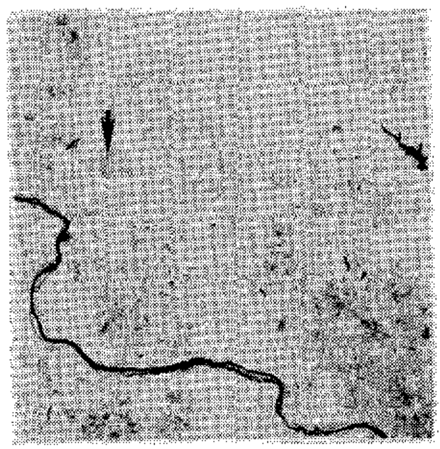
SATELLITE MONITORING OF FOREST DEFOLIATION

23 SEPT 1972 MSS 5
E-1062-15190-5

2 JUNE 1973 MSS 5
E-1314-15195-5



23 SEPT 1972 MSS 7
E-1062-15190-7



2 JUNE 1973 MSS 7
E-1314-15195-7

IMAGERY OBTAINED FROM ERTS-1 ON 23 SEPT 1972 SHOWS FOREST STANDS AS DARK TONED ON MSS 5 AND LIGHT TONED ON MSS 7. IMAGERY OBTAINED ON 2 JUNE 1973 INDICATES DEFOLIATION OF A FOREST STAND. DEFOLIATED FOREST APPEARS LIGHT TONED ON MSS 5 AND DARK TONED ON MSS 7 (SEE ARROW).

TABLE 9 : Geological Applications of ERTS

MAP PRODUCTS OF ENVIRONMENTAL GEOLOGIC STUDIES	SELECTED ERTS APPLICATIONS INCLUDES BOTH SATELLITE AND ALTITUDE AIRCRAFT IMAGERY
° Bedrock geology	° Fracture, lineament; and structural trend data
° Surficial geology	° Alluvial flood plain mapping
° Depth to bedrock (thickness of surficial deposits)	
° Mineral resources (including sand and gravel deposits)	° Delineating mined out areas, gob piles
° Water resources	° Monitor suspended loads in reservoirs, provide surface fracture data applicable for groundwater development
° Solid waste disposal	° Site location related to land use
° Liquid waste disposal	° Fracture data applicable
° Current land use	° Monitor land use changes
° Stream sedimentation and suspended load analysis	° Monitor sediment and pollution plumes
° Flood-prone areas	° Flood Monitoring and delineation of potential flood plains

(1) linears which are unrelated to stream, river drainage, or cultural features;

(2) linear topographic features which are transverse to the trend of major valley and mountain systems, such as antecedent stream valleys and wind gaps; and

(3) stream and river course alignments, especially on the coastal plain.

Most of the lineaments are presumed to be the surficial expression of fractures or large joints in bedrock along which there has been no appreciable movement. However, some of the lineaments may be surficial expressions of buried faults (breaks in the bedrock along which there has been movement of one side relative to the other side) which have gone undetected in previous geologic mapping.

The principal applications of lineament mapping in environmental geology are: (1) identifying potential excavation and construction hazards; and (2) identifying areas of favorable water well yield. Lineaments, or faults and fractures, are zones of weakness in the earth that should be carefully studied in planning for large buildings, dams, and bridges; they are also known to be areas for ground water recharge and accumulation. Lineaments which are fractures can pose problems for deep excavations and foundation construction. Lineaments which are faults represent zones of potential earth movement and earthquake activity. Both types of lineaments are represented by zones of broken rock which are ideal locations for drilling water wells.

ERTS imagery is also suited for mapping and monitoring locations of minerals and sites where they are developed. Planners have two responsibilities in this area: to monitor the extraction process and the rate of recovery to assure that environmental safeguards are protected; and, to assure that important mineral deposits remain accessible for future use. Accordingly, the planner carries out his proper function of protecting the welfare of present and future populations and the natural environment.

Areas of potential deposits of construction materials -- sand, clay, gravel -- can be identified in the Baltimore-Washington corridor from ERTS imagery (Figure 23). Both active and abandoned sand, gravel, and clay pits are identified on a 1:250,000 scale enlargement of an ERTS image acquired on October 11, 1972. The pattern these locations exhibit, combined with photogeologic study of the surrounding area, identifies where probable additional deposits can be found. This does not mean, however, that the areas shown will yield these materials; it only means that the geologic prerequisites for their existence have been observed. With this information, geologists may focus their efforts on smaller areas and identify actual deposits by more detailed mapping. Planners may also introduce public land use controls to preserve these areas for future use.

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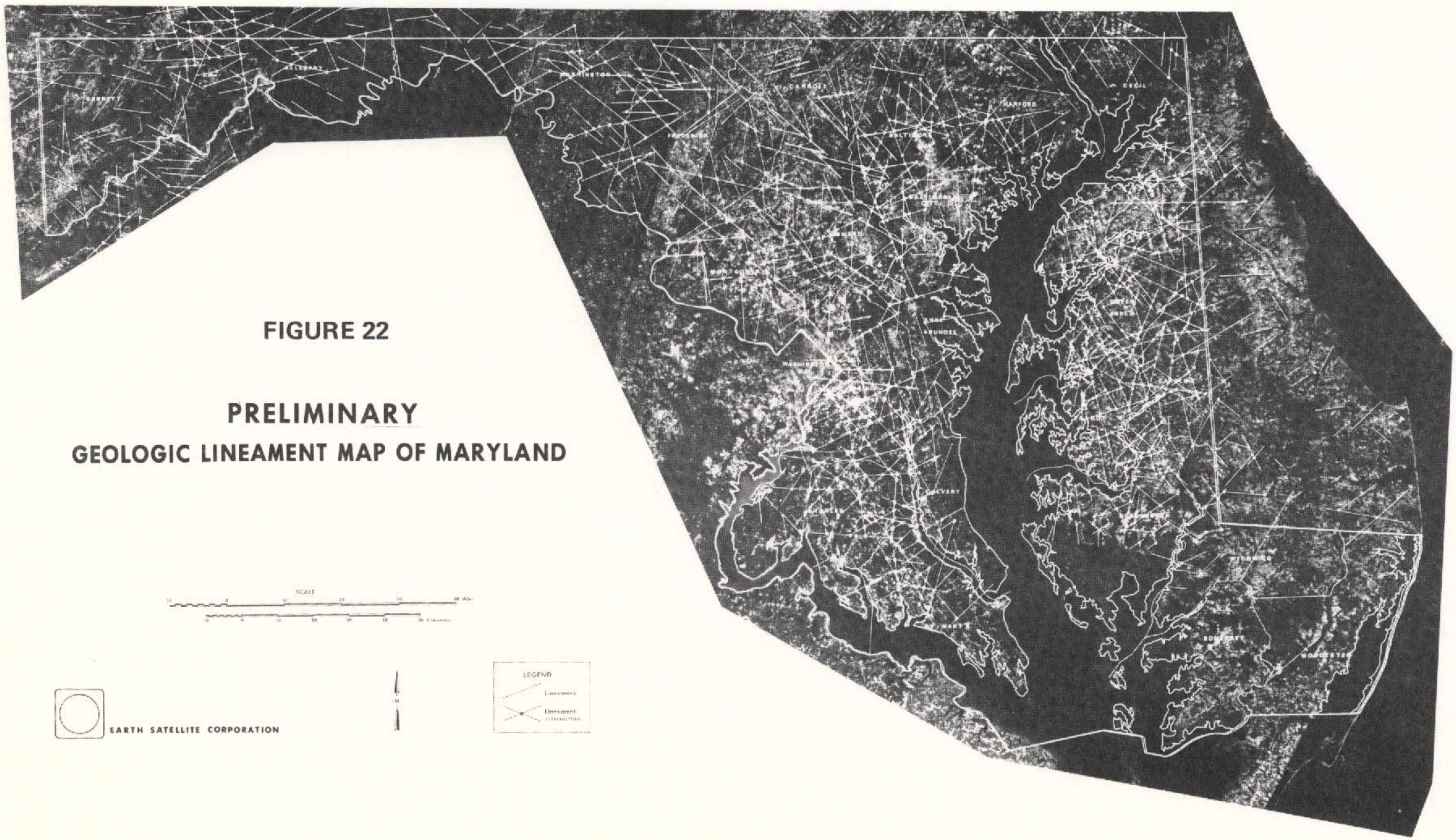
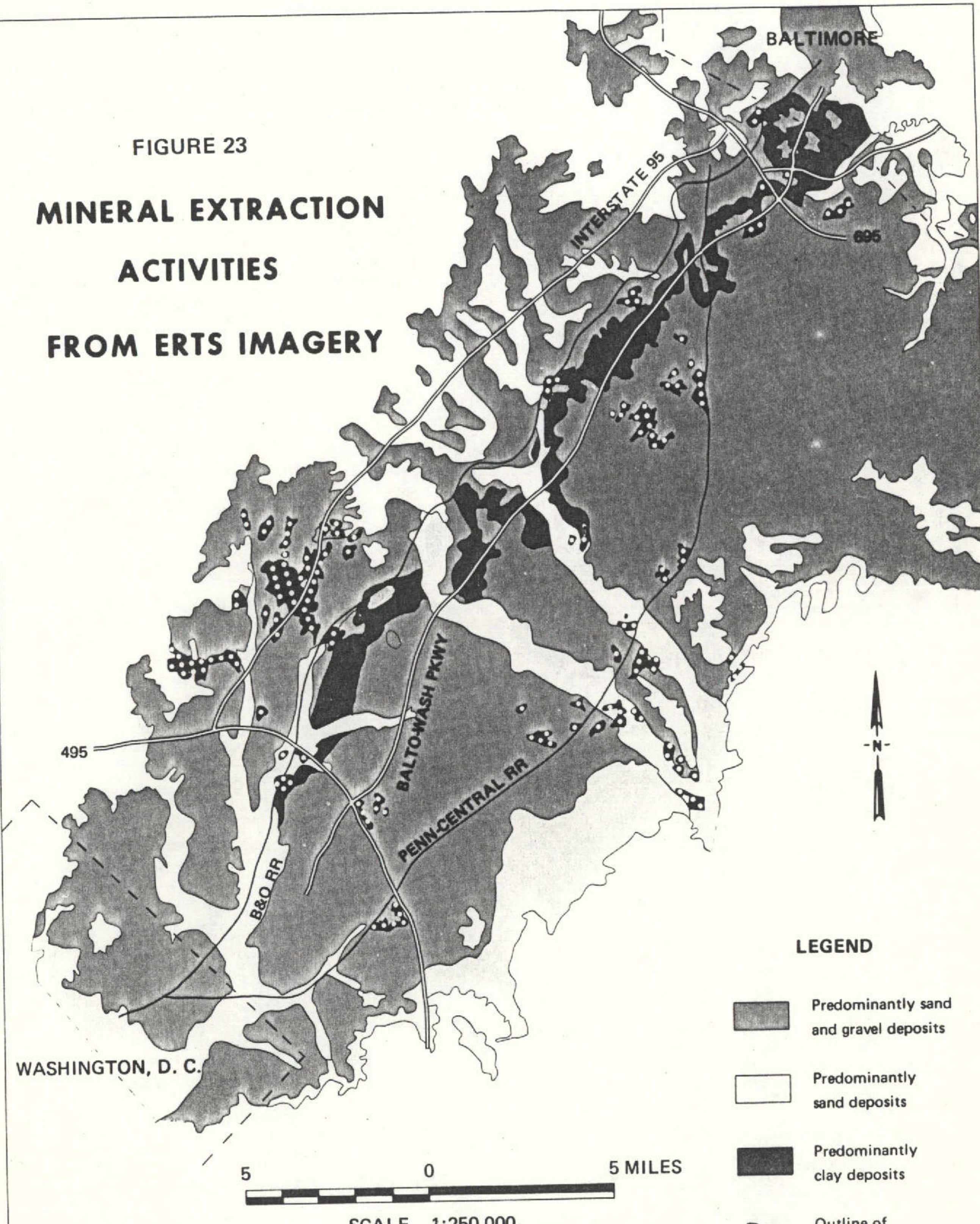


FIGURE 22

PRELIMINARY
GEOLOGIC LINEAMENT MAP OF MARYLAND

FIGURE 23

MINERAL EXTRACTION ACTIVITIES FROM ERTS IMAGERY



Map of the Baltimore-Washington Corridor area showing outline of potential sand, clay, and gravel deposits and outlines of all active and abandoned pits for these materials. Pit outlines from 11 October 1972 ERTS imagery and checked by June, 1973 U-2 aircraft photography.

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Analysis of Water Resources

The maintenance of water quality in the upper Chesapeake Bay is important to recreational users of the region: boaters, fishermen, swimmers. Sediment control is important on navigable waterways, for example, Baltimore Harbor, to assure proper depths for navigation. Surrounding these waters are extensive agricultural lands supporting crops and pasture, urban activities, including residences, commerce, and industry, and the facilities associated with maritime trade. Sources of material that degrade water quality thus can be inferred from the land usage and from supporting meteorological, soil, and geologic data.

Suspended materials can be detected on ERTS-1 imagery in the rivers of the upper Chesapeake Bay. Most of the material in the rivers was sediment, whereas most of the material in Baltimore Harbor water was industrial effluent.

It would be useful to planners if sediment could be traced to its source. Guidelines could then be established to prevent soil loss and its consequences: siltation in navigable waters and sediment choking of estuaries. This study demonstrates a procedure for identifying source areas of suspended material and a method for inferring the nature of suspended material.

The rivers studied include the middle branch and the Northwest Harbor of the Patapsco River, Back River, Middle River, Gunpowder River, Bush River, Elk River, Bohemia River, Sassafras River, and the Chester River. Two of these rivers were selected for closer examination: the Bohemia River and the Patapsco River (including the Northwest Harbor and the Middle Branch of the Patapsco). In the Bohemia River drainage basin, for example, land uses are primarily cropland and pasture, with deciduous forests along tributaries; soils are predominantly upland deposits of medium to coarse-grained, highly erosive sands and gravels with minor amounts of silt and clay.

Periods of rain in this area are typically followed by a runoff carrying heavy loads of surface material. ERTS-1 imagery, MSS Bands 5, 6, and 7, are most useful for studying these events. High sediment concentrations were observed in the Bohemia River on July 7 and 8, 1973 imagery, following heavy rainfall three days earlier (July 4). Observations at two nearby stations recorded 4.58 inches of precipitation (Middleton, Delaware), and 2.60 inches (Elkton, Maryland). Figure 24 illustrates the heavy sediment load in the Bohemia River.

Land use and soil types near Baltimore Harbor differ substantially from those near the Bohemia River. Land uses have been mapped as single family residential units, wholesale services and light industry, open land, and marine terminals. A small percentage of open ground and vegetation and a high percentage of impervious surfaces in this area assures that water runoff will be voluminous and contain residue from streets, such as hydrocarbons of various types and untreated wastes.

Plumes were observed in the Patapsco River on four separate ERTS overpasses -- 4 April 1973, 1 June 1973, 8 July 1973 and 22 January 1974 -- all of which were associated with varying amounts of rainfall prior to the overpass, except in the latter instance. The overpass of January 22, 1974, had no preceding rainfall and, furthermore, there was no suspended sediment in rivers north and south of the Patapsco River. From these facts it seems possible that the plume observed on MSS Band 7 of that date is some type of industrial effluent. It issues from a creek that is the confluence of two small creeks, Deep Run and Stony Creek (Figure 25).

Such data allows the planner to determine whether the existing land use is adversely affecting water quality to an unacceptable degree. Requirements may be developed, e.g., to maintain some type of soil cover between crops, to lower the potential for soil erosion, and to regulate types of waste discharge allowable in rivers and streams.

ERTS-1 IN THE EVALUATION OF LAND CAPABILITY/SUITABILITY

Capability/suitability analysis refers to evaluating the potential uses for land according to physical, social, economic, and institutional criteria. In the Maryland State Department of Planning land use plan work program, "capability refers to the ability of the land to support particular uses based on the physical characteristics of the land" (Figure 26). This differs from the U.S.D.A. Soil Conservation Service and American Society of Agronomy evaluation of physical characteristics which are called a measure of the land's "suitability," i.e., for agriculture.

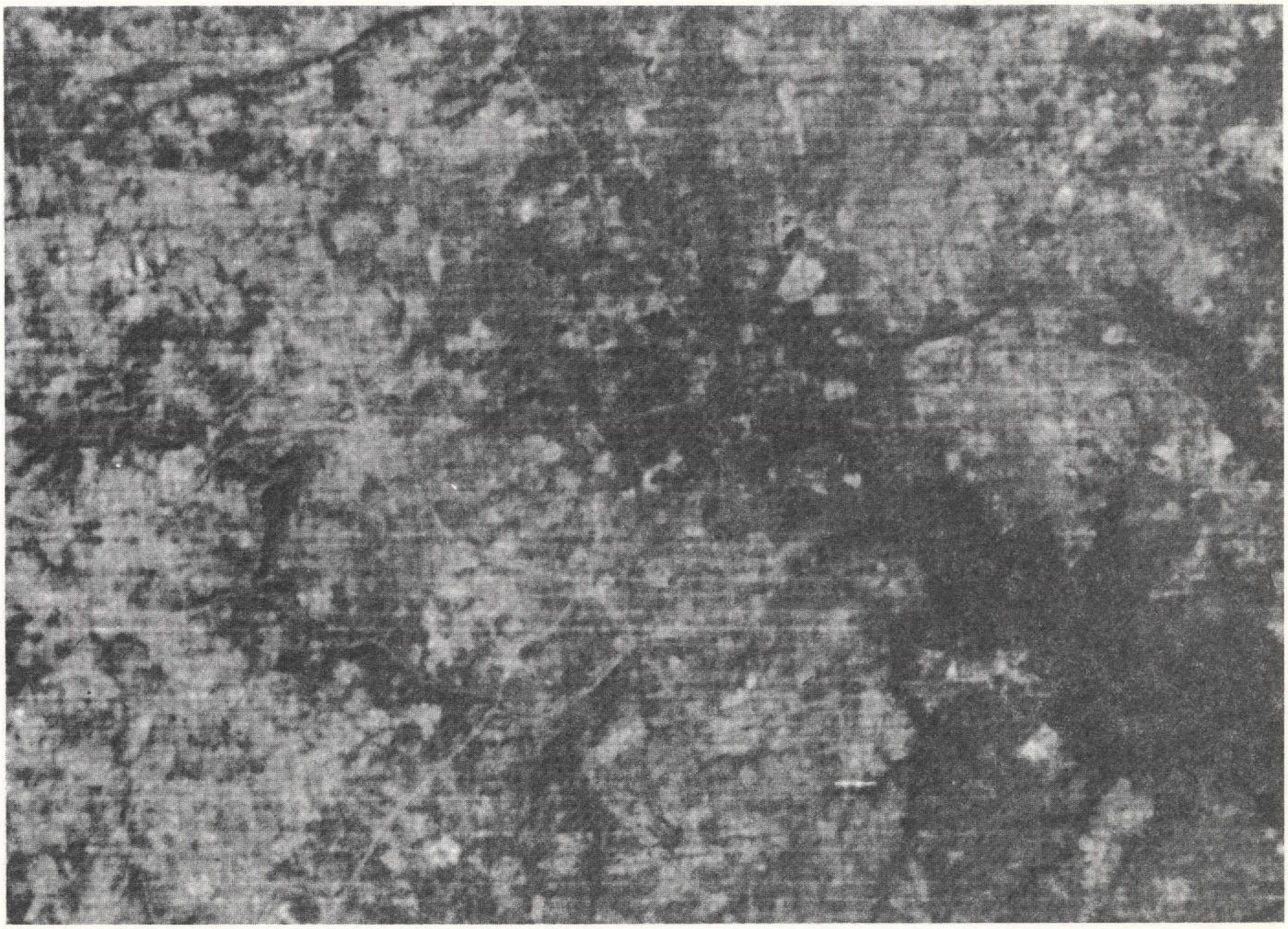
The actual use of land is as much a function of the social, economic and other systems as it is a function of physical capabilities. For example, a parcel of land may have good soil and water, but because of its location near the central business district of a small city, its suitability in an economic sense is not agriculture but some form of commerce or industry; in a social sense its suitability may be ranked high as a park or open space. In other words, determining capability and suitability is based equally on endogenous factors and exogenous factors. Suitability analysis relates characteristics of the land to a social-economic-institutional situation apart from the land, weighing each factor to arrive at an evaluation. In recent years the scope of planning has changed to reflect currently important social issues, raising the importance of this type of analysis.

The land use planner has traditionally recognized the concepts of capability and suitability, but has not had reason to articulate them as clearly as he has recently done. Prominence has been given to certain types of planning because states across the nation have made them mandatory in planning laws, e.g., housing, public safety, and the environment. As a result, the task of planning has taken on new dimensions where the planner has had little experience and must adopt the appropriate techniques and build credibility.

FIGURE 24 - Silt content in the Bohemia River, Maryland on ERTS

This enlargement covers approximately 1000 square miles.

FIGURE 25 - Effluent in the Baltimore Harbor on ERTS



This enlargement covers approximately 1000 square miles.

LAND USE CAPABILITY / SUITABILITY CONCEPT

CAPABILITY: ABILITY OF A RESOURCE TO SUPPORT VARIOUS ACTIVITIES, AND VARIOUS LEVELS OF ACTIVITIES, BECAUSE OF INHERENT PHYSICAL CHARACTERISTICS

PARAMETERS:

- SOILS
- GEOLOGY
- MINERALS
- TOPOGRAPHY
- GROUND WATER
- SURFACE WATER
- VEGETATION
- WILDLIFE HABITAT

SUITABILITY: CULTURAL ENTITY ALLOWING PREFERENCE THAT LAND RESOURCES SUPPORT VARIOUS LEVELS OF ACTIVITIES GIVEN EQUAL CAPABILITY ALTERNATIVES

PARAMETERS:

- OWNERSHIP
- WATER / SEWER PLANS
- TRANSPORTATION SYSTEMS
- HISTORIC SITES
- EXISTING LAND USE
- GOALS AND POLICIES
- PLANNING AND PROJECTIONS

FIGURE 26

Decision-making with regard to purposes land can serve and might serve requires qualitative judgments based on information that tends to be voluminous. Within the last ten years, there have been numerous attempts to develop procedures to obtain and interpret land-related geographic data objectively. Two technologies have resulted: the technology of remote sensing for obtaining current data, and the technology of automated information analysis for processing data and testing alternative decision strategies (modeling). Planners are increasingly coming to depend upon these technologies; they are outgrowths both of the demand situation among the planning community and the supply situation. Both technologies have demonstrated capability to produce and assimilate large quantities of data at a cost that is steadily declining. At the same time, timely and accurate information has improved the decision-making process and the quality of decisions.

Background

The previous discussions addressed the concepts of capability and suitability and placed them in the context of a type of information presently used by state planners. The following discussion explains how the demands of the Maryland planning program necessitated a major modification of the scope of the experiment that permitted this type of analysis to be done.

In the initial phases of this investigation, it was determined that although there were many types of data available in the State in various maps, records, statistics, and reports, the multiplicity of formats made their use in the planning program as well as the experiment difficult and inefficient. To satisfy either set of objectives corroborating the results of ERTS-1 analysis, or capability/suitability analysis, the data were in need of substantial modification. The requirements of the Statewide General Plan program were more demanding and specific.

For example, of the two means available for handling spatial data -- analog and digital -- the former would not allow the kinds of analysis necessary in the State's planning program. The analog system, often referred to as a system of "plastic" maps, involves the construction of overlays. Its limitations are well known: overlays take considerable time to prepare; the information content is often held low to give the overlays greater utility in a number of uses; updating requires them to be reconstructed; and they are difficult to handle and store. The State's planning program, however, and its capability/suitability analysis, expressly required means of synthesizing earth resources spatial data.

An alternative to the analog system, the geobase computer system (digital), not only allows for synthesizing data, but permits updating with ease. Map and statistical data may be digitally encoded without physical limitation to the number of variables or categories within variables; limitations are based on the usefulness of the information and cost, not on system capability. Format differences are rectified as the information is digitized into the system. Both quantitative and cartographic analyses may be performed concurrently, and updating can be done on a selected basis. For these reasons, and a cost comparison which showed the digital procedures would be less expensive, the digital system was chosen as the proper tool for the various tasks of the planning program. Funds were provided from the State of Maryland, the Federal Department of Housing and Urban Development, and, to a limited extent, from the National Aeronautics and Space Administration.

The following analysis presents the type of information that is derived from capability/suitability analysis. It also describes how the geobase information system was developed to provide this information. The section concludes by describing the ways modeling tasks may be performed with the system, and how a continuous stream of information is used in the modeling procedure. The role of ERTS-1 and other remotely sensed data will be discussed as a means of constructing information systems and models and in exercising and maintaining them.

The Demand for Information

Land use planners see the landscape more in a "holistic" manner than they had prior to the last decade; that is, planners have come to view the landscape as a system with two elements -- man and the land -- interacting to different degrees, differing in time and space, that can be divided into sub-systems containing these elements in different associations. The most basic task of capability analysis is to focus on the physical landscape and to identiy its various elements and their characteristics in an appropriate section of the total physical landscape; capability analysis determines the interactions between elements that create patterns on the landscape, e.g., land use, and lead to change. Other tasks will be discussed in the appropriate places.

The first stage of capability analysis is to acquire information concerning the geology, soils, vegetation, hydrology, and the atmospheric conditions appropriate to the site in question. These data are derived from published sources, the various scientists in each of these areas, and current observations. They must be integrated in such a matter that comparisons can be made with the requirements of each potential land usage. The data, understandings and concepts must be sufficient to show:

(1) the fundamental physical parameters weighted in terms of the capability of a land unit to yield natural products, or to support particular uses;

(2) the demonstration that certain land units are inherently more appropriate for certain uses than other units because of natural limitations and constraints;

(3) that capability is neutral with respect to preference between competing uses of equal weight; and

(4) that weighting is most satisfactory if categories for a given use are restricted, e.g., high, moderate, low, unsatisfactory, not applicable, etc.

Suitability analysis refers to using factors external to physical characteristics to determine the appropriateness of a specific activity both in relation to the capability of the land resource (with due respect to existing patterns of use) and to the political-social-economic environments (including policies and regulations already in force). From suitability analysis, informed choices are made designating particular land areas for specific land uses or alternative uses.

Methodologies: Capability/suitability analysis, involving a wide variation in information and perspective, requires a flexible means of weighting information used in the actual analytical process so that the inevitable problems of merging diverse information can be resolved. Weighting by the specialists themselves allows land planners, whose professional competence generally lies outside these areas, to judge the relative importance of each criterion in land capability/suitability decisions and to establish the necessary trade-offs.

The geobase information system is an automated way of assimilating, storing, and retrieving all the data that relate to earth resources, in various combinations specified by the user. It has become a major tool for the planner in this type of analysis because it provides a means of automatically surveying vast amounts of data, weighted or standardized for comparison with other data, and combining them in various ways. An advantage of the more advanced systems is that they allow for modeling activities, i.e., postulating a set of events and probable consequences of these events in a procedure that simulates their interaction in the environmental/social system and produces a set of outcomes for choice by the decision or policy-maker.

Realizing the potential benefits of an automated geobase information system, the Maryland Department of State Planning initiated a program with the Environmental Systems Research Institute (ESRI) of Redlands, California to develop a statewide planning information system. A part of this program consisted of an experiment to determine the role of remote sensing and satellite remote sensing systems in providing base data for the construction and updating of the system. The basic tasks in building the system were:

(1) the selection of significant geographic indicators which influence intelligent decision-making for land use planning and management;

(2) the collection of existing base maps and creation of new base maps which describe significant geographic variation according to the selected indicators;

(3) the development of automated computer files for geographic data (i.e., digital files of spatially referenced map informati

(4) the design and development of computer programs and procedures for storage, analysis, retrieval, and update of the digitized data;

(5) the development of computer models for the analysis of data to be used for planning decisons; and

(6) the development of in-house capability for operation of the system; specifically, training State agency personnel in the use of the system.

The first of these tasks necessitated selecting a form of classification for geographic variables which would provide information for the complex planning decisions made by the State. The selection process required the evaluation of existing data in the State as well as potential new data to be collected. In this context, selected indicators of natural and cultural processes were chosen and prioritized, based on their significance for statewide planning.

"Soil" is an example of a high priority data item. The soil classification scheme provides interpretations such as areas that have unstable land for construction, areas that may be within a floodplain, wetland areas, areas with high potential productivity for farming, etc.

The second task involved collecting existing maps and creating new maps for the entire State. This task, one of the basic requirements for development of the system, drew upon information collected remotely from satellite and high altitude photographic sensors as well as drew upon published sources. Various Federal, State, and local agencies and private groups were contacted to acquire and develop consistent data maps suitable for digitizing into machine readable files. Eight variables were collected to indicate landscape capability. These variables included soils, geology, aquifers and aquifer recharge areas, mineral resources, topography, natural features, vegetation, and surface hydrology. Five additional variables were collected for the purpose of conducting suitability analyses. Suitability is defined by the State as "an entity (usually man-made, induced, or influenced) that allows one to indicate preference that a resource support various levels of activities given the equal capability of two areas." It is through the suitability parameters that the present land use, existence of public facilities, and various planned activities are accounted for. Suitability variables collected for this study included publicly-owned property, sewer and water facilities, transportation systems, historic sites, and existing land uses.

The third task was the development of automated data files describing the mapped variables listed above. These data files were essentially computer readable maps stored in a format facilitating application to a variety of analytical planning efforts. The method of "digitizing" utilized a grid cell and polygon identification procedure to identify various points, lines, and areas of geography as described on the original maps for the State.

The fourth task was the design and development of computer procedures and programs for the storage, analysis, retrieval, and display of the data contained in the automated files. This required the development of a flexible system which would not only efficiently process and maintain the existing data variables, but which could also handle new data without significant difficulty. This flexibility includes the capacity for updating the files with new information related to changes in land use, transportation, etc. This task culminated in the development of an integrated software system to be used as a "tool box" for data handling and planning analysis.

The fifth task involved transforming the data bank files into meaningful information maps for land use planning decisions. An automated procedure was used to overlay data variables and weight them according to specified values related to the capability and suitability of the landscape to sustain various land uses.

The sixth task involved the training of State agency staff in the use of the planning information system. The consultant part of the investigation team assisted State personnel in learning the software procedures and how they could be used to conduct various forms of analysis using the digital data files. This task also included setting up the software at the State facility and conducting a seminar series for users in ways of operating and applying each of the programs for specific analysis and mapping.

The Maryland Automated Geographic Information System (MAGI) required as input various maps of those natural resources (e.g., soils, vegetation, mineral resources, etc.) and cultural geography (e.g., land use, transportation, etc.) selected as indicators for land use planning. These maps depict three types of information of geographic interest: polygons, lines, and points. The polygon maps define the boundaries of homogeneous features as well as the characteristics associated with those features (e.g., a soils map describes the boundary characteristics of soil types). Line maps define the linear elements of the landscape such as roads, hydrologic networks, railroad lines, etc. Point maps locate the geographic position of events or phenomena located at specific points (e.g., historical landmarks, wells, or traffic intersections).

The MAGI system "geocodes" or places the geographic location of all three of these categories into digital data readable by the computer. All data are "geocoded" by reference to a common geographic reference system or projection: the Maryland Coordinate Grid System. The procedure for referencing the variables on these maps to the State grid system involved assigning the geographic data to a grid cell lattice covering the entire State. A cell size of 2000 foot by 2000 foot (approximately 91 acres) was chosen for encoding and digitizing because it was compatible with the divisional breakdown of the 10,000 foot State plane lines (25 cells) inscribed on the base map used for digitizing, as shown in Figure 27.

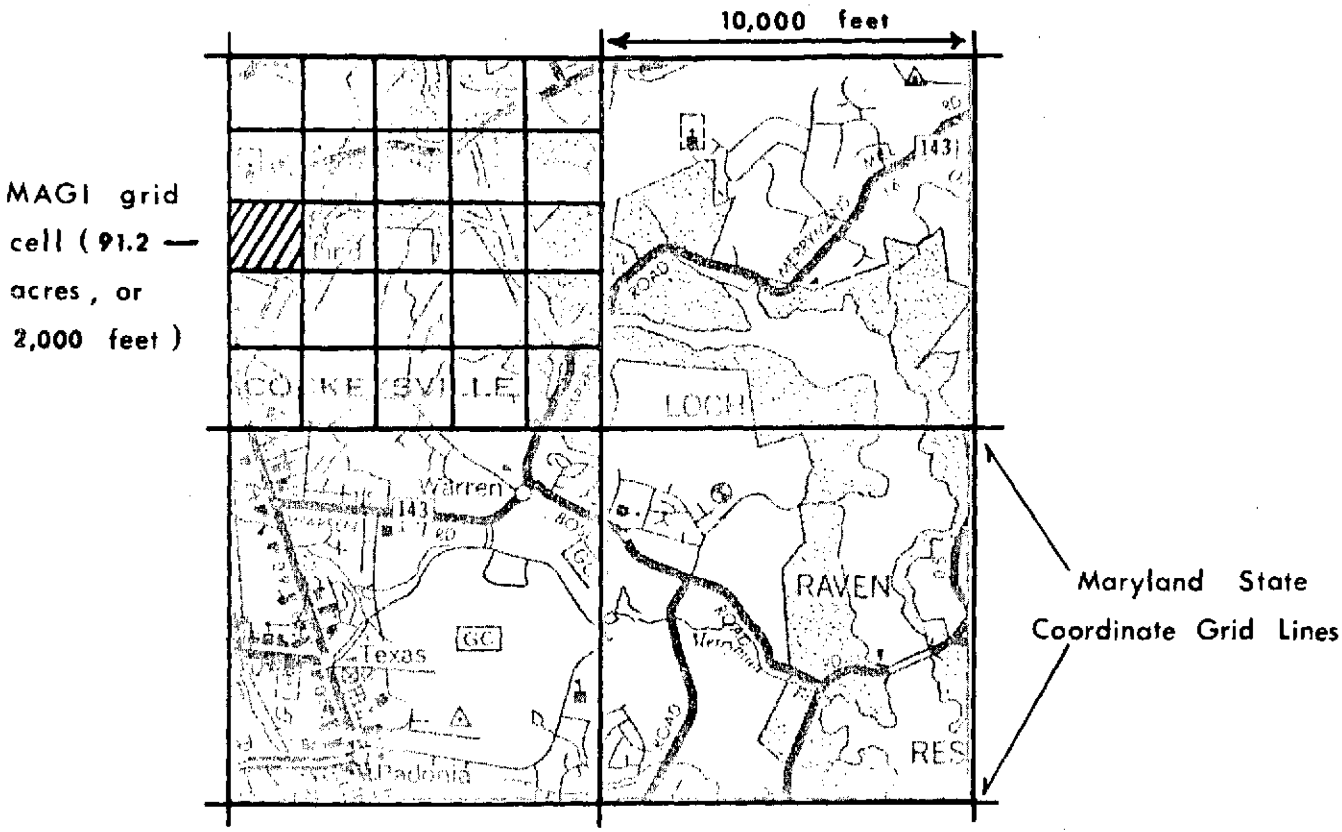


FIGURE 27: MAGI Grid System

From this information base, planners can request simple data listings and display maps for such variables as soils, geology, land use, etc. Data can be displayed on these maps using shades of grey to quantitatively depict various interpretations (e.g., geology for Western Maryland Figure 28).

For many applications, however, more sophisticated forms of analysis are required. For example, suitability maps for housing development might require the combination or overlay of a soils map, a vegetation map, a slope map, an existing land use map, and other maps describing spatial variation. For this reason, the MAGI system was developed as an overlay system. The overlay process is conceptually similar to the manual overlay of plastic maps describing variations in geography (e.g., soils, geology, vegetation, etc.) at a constant location. The automated computer files in the system contained each variable according to a matrix of numerical codes. These digital matrices can be overlaid to create a numerical composite, subsequently produced in map form by the computer (see Figure 30). Normally, this is accomplished by assigning values to the variables according to some interpretation. For example, the combination of information concerning soil type, topographic slope, and vegetation type can provide a generalized picture of the erosion properties of a given area. This determination requires the development of quantitative indices of soil, vegetation, and slope as they relate to each other and as sub-classes relate within major classes. In this way, qualitative variables are interpreted and combined quantitatively to express some conceptual understanding of landscape processes, capabilities, and suitabilities.

The utilization of various computer programs and procedures enables the acquisition of data for the entire State or any given geographical sub-area within the state (e.g., county, watershed, etc.). The use of this quantitative interpretation and weighting technique provides planners with a modeling methodology not previously possible with the use of manual techniques.

Applications

The applications of the system fall into three categories:

(1) planning and analysis studies (e.g., overlay analysis, gravity/search analysis, etc.);

(2) project or plan review (e.g., environmental impact analysis);

(3) basic data retrieval (i.e., maps, data listings, summaries, etc.).

The modeling seqment of the MAGI system is one of its most important capabilities because it involves the interpretation and use of the geographic data system for specific planning applications.

The term "model" used in this project is defined as a set of scales and relationships among geographic data which articulate a geographic condition or set of conditions. Most of the models developed for this project were descriptions of the suitability and capability of the physical landscape to support various land uses. As input to these models, various combinations of the data bank variables were used.

The final output of these models was a series of grid cell maps defining the capability or suitability for specific kinds of land use activities. Each grid cell is assigned a value which expresses weightings reflecting one or more environmental characteristics of that cell or surrounding cell(s). The weighting of the environmental characteristics was established by analyzing the constraints and amenities of each data variable relative to all other variables, and finally relative to a specific land use activity being examined.

The best way to conceptualize this process is to imagine a map of a model describing "where best" housing should be located. Within this model, flat slopes and good soils would be given a higher weighting than steep rocky slopes because they are easier to build upon, and their use for residential development would normally result in the destruction of the fewest environmental resources. By developing this very simple model as a computer program, one could very quickly map the locations where residential land use should best be located and where it should not be located.

The models can become extremely complex with many variables and decision points. In these situations, a matrix or flow chart is normally employed to illustrate the data relationships and weightings used as criteria for a model.

An example of how a matrix technique is used is shown below. If slopes are an important consideration for certain developments, the degree of constraint may be indicated by slope phase (zero being no constraint, five being maximum constraint).

		SLOPE PHASE			
		(0-3)	(3-10)	(10-20)	(20 and above)
Land Use	Residential	0	1	3	5
	Industry (6)	0	3	5	5

If depth to bedrock is being considered and weighted, the matrix of model relationships may read as follows:

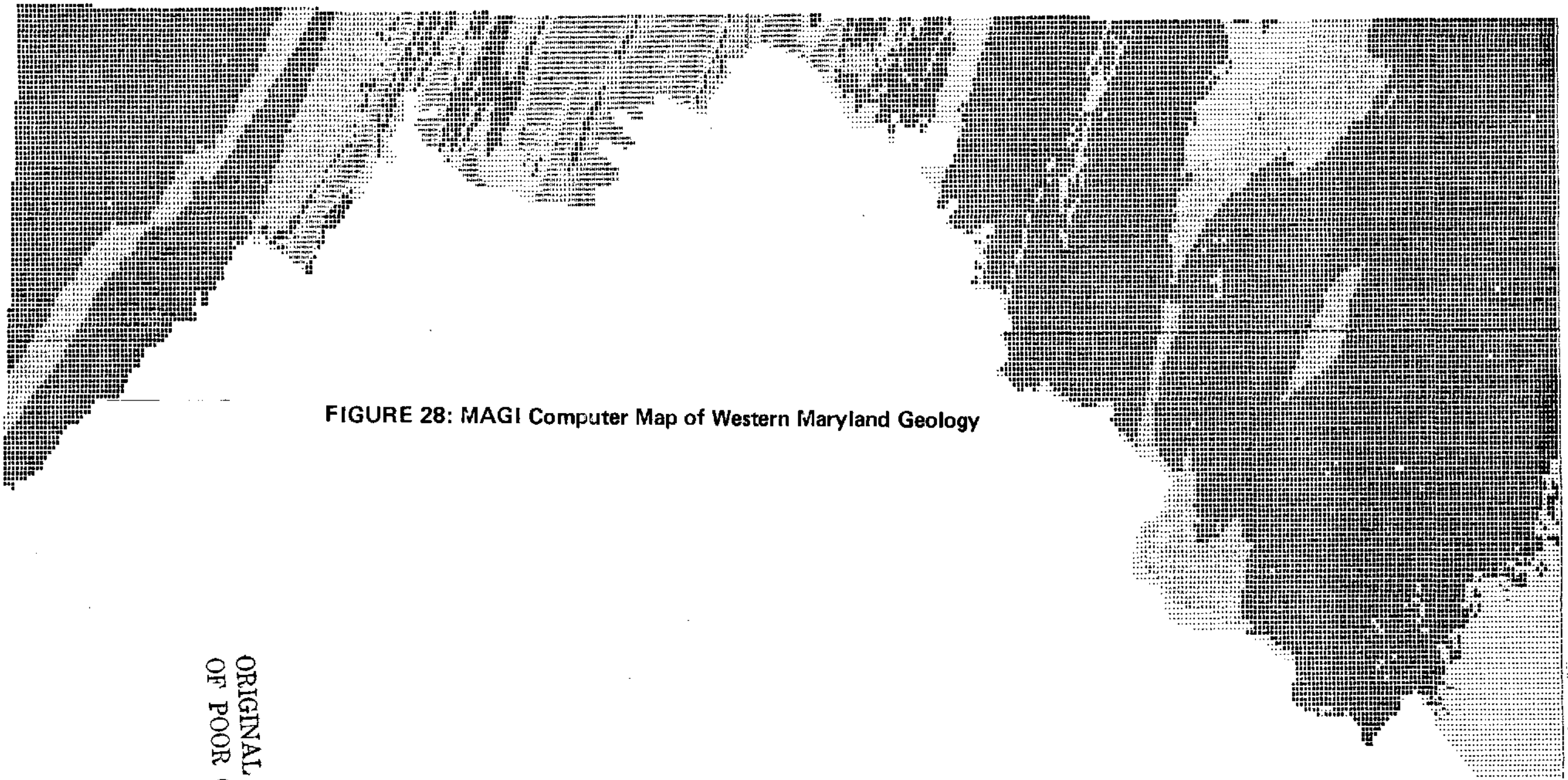


FIGURE 28: MAGI Computer Map of Western Maryland Geology

DEPTH TO BEDROCK

		(0-18")	(18-36")	(3'-6')	(6'-12')
	Residence w/o basement	2	1	0	0
Land Use	Residence w/ basement	5	4	4	0
	Industry	5	5	5	1

The weightings then can be integrated mathematically for any combination of slope phase, depth to bedrock, or land use activity by using a matrix.

A portion of the matrix may read:

SLOPE PHASE/DEPTH TO BEDROCK

		(0-3%/0-18")	(0-3%/18-36")	(0-3%/3'-6')
	Residence w/o basement	2	1	0
Land Use	Residence w/ basement	5	4	4
	Industry (6)	5	5	5

The selection of the weighting factors can be both a subjective and objective process. When values are subjectively determined, they should reflect proposed policies, standards, and criteria which are generally acceptable. Changing the values or their relative rankings within a model can be considered a simple form creating alternative interpretations for plans based on alternative policy and standard criteria. Changing individual values may substantially alter the output, depending on the sensitivity of the weighting and the degree and type of interrelationships among the variables.

Objectively weighted models can also be developed. These models typically require more time and involve some form of scientific analysis and/or statistical analysis to generate appropriate values. An example of this type of analysis is regressing, whereby samples of existing or historic phenomena are studied in terms of their mathematical correlation with specific variables (e.g., the probability of housing being located in a specific grid cell is some function of land cost, accessibility, employment, environmental, legal, and engineering constraints, etc.). This modeling/weighting process can be thought of as an organizational structure for defining, testing, and expressing consistently the geographic processes, limitations, and amenities of natural and cultural landscape as mathematical relationships.

In developing a model of this type, there are three critical components:

(1) definition of the specific objective of the model;

(2) specification of the data variables that are critically related to the objective to be interpreted; and

(3) development of data relationships and weightings which express objectively some cultural or natural process or are responsive to a legitimate set of subjectively derived criteria or policies.

Because of the complexities of land use processes, it is not normally practical to construct a single model to describe a host of land use capability and suitability interpretations. The questions of land use are sufficiently complex to warrant the development of a series of independent models that can stand alone or be used in combination during the planning process.

In the development of a model, it is sometimes useful to segregate various geographic interpretations into sub-elements which together form the structure of the total model. For example, when developing a model of suitability and capability for low density residential development, one might hypothetically define the following considerations:

(1) <u>capability considerations</u>: environmental hazards, engineering construction problems, amenities of landscape.

(2) <u>suitability considerations</u>: access (transportation), cost of land, conflicting land uses, social, economic, and environmental impact resulting from the project.

Each of these considerations has a series of data indicators which might be used in selecting or evaluating the constraints and amenities of a geographic location for this residential development. When developing the model criteria, it is useful to examine the indicators in the context of dynamic geographic processes which, when combined and weighted properly, provide the interpretation desired. For example, when evaluating environmental hazards, one might consider a series of landscape process models such as potential for flooding, mass movement, erosion, etc., as building block components of the total capability analysis.

One of the most important factors in developing a model is a thorough documentation of the decisions and weighting criteria used. This rule applies to both objective as well as subjective interpretations. They must be well thought out and presented for discussion and interpretation. This is particularly critical when the final interpretation is to reflect public policy.

Specific Maryland Models

The selection of models for the initial application of the MAGI system was based on their application to the Generalized State Land Use Plan. The models related, primarily, to the "actions" of land use (i.e., the activities of man to be considered in the planning process, specifically relating to geographical location). The models were designed to reflect those land use actions most directly related to public involvement (e.g., public recreation areas) and those internal considerations which reflect public policy (e.g., conservation of agriculture, environmental impact, etc.).

Since the final product in this case is the State Land Use Plan, there was considerable justification for developing models having direct relationship to the categories of activities that may be addressed in the Plan.

The following models were developed to formulate the core of the planning process. A short description accompanies each model, indicating the nature of the output. It should be remembered that these models identify and rank the suitability for only those cells meeting the criteria of the models.

(1) Mining/Extraction Model - identifies, by grid cell, areas suitable for the extraction of mineral resources (e.g., stone, clay, sand/gravel, coal, natural gas, etc.)

(2) Productive Agriculture Model - identifies, by grid cell, areas best suited for intensive cropping or special practices (e.g., orchards, tobacco, dairy pasture, etc.).

(3) Urban Models - identifies, by grid cell, suitability for each of the following urban land use sets:

Urban Centers Model - areas where all functions of urban centers are included (e.g., high density residential, commercial, services, industry).

Intensive Residential Model - areas including and relating to residential centers (e.g., schools, commercial/services, light industry).

Low Intensity Residential Model - large lot or clustered development with surrounding open space containing the fabric of a community including schools, neighborhood commercial establishments, etc.

Industrial Location Model - heavy industry and large scale commercial activities. Sub-model(s) may be constructed to specifically handle ports and marine facilities, power plants, and petrochemical facilities.

(4) Conservation Model - identifies, by grid cell, areas which should be designated permanent open space, wildlife habitat, watershed, and airshed protection.

(5) Forestry Model - identifies, by grid cell, areas suitable for maintaining the State's forest product industry and other forest activities.

(6) Fishery Model - identifies, by grid cell, areas that must be managed to insure the continued viability of Maryland's fisheries industry.

In addition to the six basic models, additional sub-models were developed as supplements. They included the following:

(1) public recreation areas

(2) accessibility (re: transportation system)

(3) natural processes and hazards

(4) agriculture encroachment models

(5) tourism model (recreation sub-model)

(6) wildlife habitats

For greater clarity, the agriculture model is outlined in detail in this report.

Agriculture Model: The agriculture model was selected for presentation because it illustrates a simple technique for the comparison and interpretation of several geographic variables. The model identifies a value within each grid cell by searching for various combinations of land use type and soil series. This value is defined along an ordinal scale (i.e., one combination of soil and land use is better or worse than another combination). The model does not attempt to describe how much more suitable one combination is than another. The map created using the model ranks all grid cells in ten levels according to their capability and suitability for agriculture. Soil series is used to describe "capability," and existing land use is used to describe "suitability."

Therefore, a cell containing predominantly good agricultural soils as well as existing agricultural land use is both capable and suitable for agricultural activities. It would, therefore, receive a high value (i.e., 10) on the map. Conversely, if a cell has predominantly poor agricultural soils and contains urbanization, it would have both a low capability and suitability rank (i.e., level 1 or 0). The criteria used for evaluating soil series according to their agricultural capability was derived from Soil Conservation Service ratings.

The categories displayed on the final map are listed in the following order of importance:

Blank = unsuitable and incapable cells

1 = agricultural or orchard land use covering poor agricultural soil

2 = forest land use covering poor agricultural soil

3 = urban land use covering truck farming soils

4 = urban land use covering prime soils

5 = forest land covering truck farming soils

6 = forest land covering prime soils

7 = orchard land use covering truck farming soils

8 = orchard land use covering prime soils

9 = agricultural land use covering truck farming soils

10 = agricultural land use covering prime soils

In processing these categories, a decision flow chart for selecting various combinations of soil and land use was used (Figure 29). The chart illustrates the basic logic employed in selecting pairs of land use and soil series, as well as assigning them specific rank order for display on the map (Figure 30).

ERTS-1 Data in the Modeling Procedure

A number of computerized geographic information systems with modeling features have been developed at the State level in response to the growing demand for environmental planning, the explosion in data requirements it generated and the associated problems of acquisition, handling, and storage, and the rising importance of sophisticated planning tools to analyze these environmental land use problems. A planner must be able to simulate the effect of various policies he might recommend. This requires an information base and a means of using these data in a series of relationships, i.e., a modeling process, for testing purposes. One of the simpler tasks he must face is the development of a means of standardizing the various data bases from which environmental data are available so that he can manipulate them in various studies. In addition to this problem, he is dealing with a type of data that is unique in the planning community, environmental data, which has a dynamic character and has not been reported systematically as, for example, socioeconomic data has been in the Federal Census.

FIGURE 29

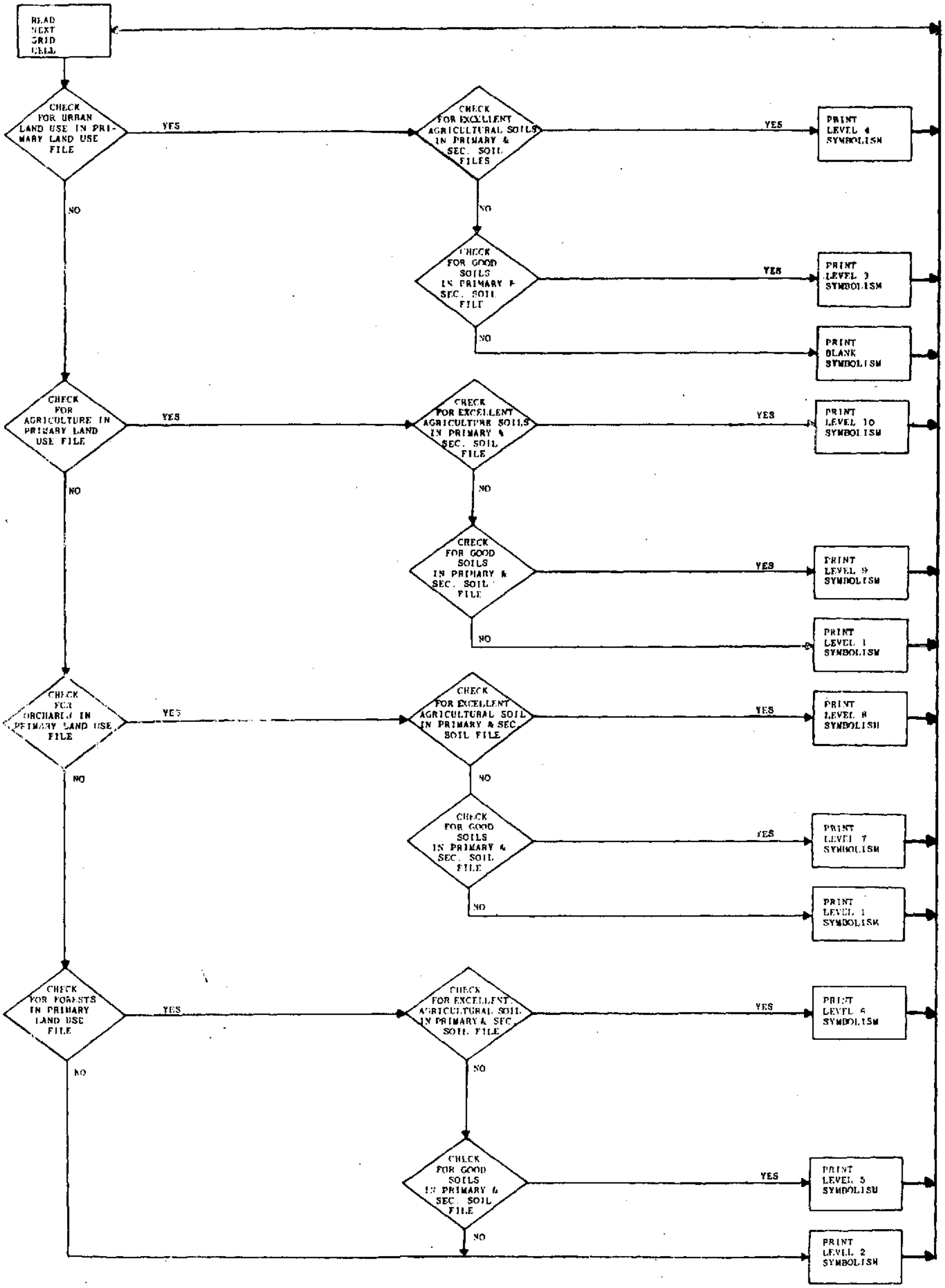


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FIGURE 30

NON URBANIZED SOILS UTILIZATION
MONTGOMERY COUNTY MARYLAND

LEGEND

- Urban
- Water
- Non-productive soils in forest and agricultural use
- Productive agricultural soils in forest use
- Productive agricultural soils in agricultural use
- Prime agricultural soils in forest use
- Prime agricultural soils in agricultural use

Land Use based on 1970 USGS maps.
Soil categories based on Maryland Natural Soils Groups, 1974.

Maryland Automated Geographical Information Systems,
Maryland Department of State Planning

EARTH SATELLITE CORPORATION

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The more complex of these models are integrated models which attempt to simulate the interrelationships between socioeconomic activities, land use patterns, and the resulting impacts on natural resources and environmental quality. These are in various stages of development and their utility has not yet been tested in the planning community.

Less complex modeling, consisting of discrete models linked with an information system, has already had applications which have demonstrated results. The core of this linkage, the information system, has already been implemented in thirteen states in varying degrees of completion and thoroughness (Arizona, Colorado, Connecticut, Illinois, Maine, Maryland, Minnesota, New Jersey, New York, Ohio, Tennessee, Texas, and Wisconsin).

Statewide information systems have the potential to influence land use planning and decision-making at all levels from the state to its lower jurisdictions. The concept directing most of these efforts is that a centralized and integrated data system made available to local decision-makers not only might standardize information use and create efficiency, but also might encourage more local agencies to implement land use planning of a higher order of environmental consciousness. In other words, the information system reflects the perception of planning at the state level as one of coordinating line and lower jurisdictional agencies and disseminating information in regard to planning problems.

These information systems, like the complex regional models to which they can be linked, are a future development in planning techniques that will have a strong impact on land use planning and the collection of earth resources data. The construction of these systems is an indication that several states already collect various land use and environmental data on the statewide level and others might follow with similar collection programs. The use of ERTS data as an input to build the initial data base and to provide for updating and calibrating capability for the models related to the system depends largely on the presence/absence of prior environmental and land use information, their quality, and the competitiveness of ERTS-generated information. It must be remembered that although a substantial information base can be formulated from published and other sources, the need to update this base is one of the chief arguments for a low cost observation system. Each state, however, will undoubtedly have different criteria for judging the merits of each type of information and source as they relate to a particular use and user community. Whether the State of Maryland's system reflects a typical user community's demands for accuracy and detail, as well as choice of topics, cannot be determined within the scope of this analysis.

ERTS-1 Data in the Maryland Model

One limitation of an information system such as the MAGI system described above is data accuracy and age. Although many efforts were made to collect the most accurate and up-to-date data, there were situations where these objectives were sacrificed for consistent statewide information. This procedure is quite acceptable in an information system built and geared for statewide or regional planning purposes because interpolation and extrapolation, both in age and quality, are generally acceptable at higher levels of decision-making. As one decreases in scale, however, the problem of discontinuous anomalies of time and space become greater; therefore additional data collection is required.

In other words, the nature of the planning program required data which was so generalized that its overall quality was not degraded by out-of-date information. At the same time, the demand for information was specific enough that it could not be obtained from ERTS-1 data. New or unconventional data must justify themselves in any of the following ways before they can become useful to the MAGI system:

(1) provide greater accuracy at a level of cost that generates a higher level of utility than present information sources can provide;

(2) provide a greater net utility than present systems by combining the advantages of timeliness and accuracy, in addition to cost; and

(3) provide timeliness and cost advantages at an accuracy that has a net advantage to the system (i.e., does not deteriorate the overall quality of the system).

The construction of the MAGI system exemplifies the role of ERTS-1 data as a complementary source of information. Although the MAGI system could accomodate information that was dated and of varying accuracy, it did require more detailed information than ERTS-1 could provide. The following information demands, listed by each category used in the system, illustrate the nature of the demand:

(1) Capability Variables:

Soils: Soil groupings were designed to respond to five basic planning considerations: fertility, stability, permeability (runoff potential and septic capability), erodibility, and alluvial floodplain identification.

Geology: Geologic data from an existing study that focused on the engineering capability of geologic materials were determined to be useful in the General Plan program. The interpretive capabilities of this data include hardness, excavation requirements, extent of rock weathering, durability of fresh rock, and overburden thickness.

Aquifers and Recharge Areas: Aquifer information used includes recharge areas directly correlated to specific geologic formations and depth of occurrence of water yielding source.

Mineral Resources: Mapping units were developed based on geologic formation boundaries that related to mineral extraction activities, including deep coal mines (active and inactive), strip coal mines (active and inactive), sand and/or gravel pits, stone quarries, clay or shale pits, greensand areas, diatomite areas, gas fields (under development, in operation, used for storage), peat pits, copper deposits, gold deposits.

Slope: Classes were developed where slopes ranged from 0-3%, 3-10%, 10-20%, and greater than 20%.

Natural Features: Maps were developed that included a wide range of unique natural areas and landmarks as well as areas enveloping particularly fragile ecologic systems and wildlands, e.g., bald eagle, osprey, and heron nesting areas.

Vegetation: Forest types were delineated that include the following types: aspen-pin cherry, northern hardwoods-white pine, white pine-hardwoods, oak-white pine, white pine, hemlock, northern hardwoods, scrub oak, chestnut oak, oak-hard pine, hard pine (pitch, shortleaf and Virginia pine), white oak, red oak, cove hardwood, river birch-sycamore, bottomland hardwoods, loblolly pine, loblolly pine-hardwoods, hardwoods-loblolly pine, red gum-yellow poplar, southern white cedar, southern cypress, and hard pine-oak. Both species and density of stand were important data for this classification.

Surface water quality: Water quality characteristics were compiled for all second and third order stream systems within the State. Additional information on designated oyster and clam beds, indicating location and distribution of shellfish harvesting regions, was added to the base maps (originally mapped at 1:20,000 scale). Combinations of the above data were made, including: Class I waters (general use and recreation), Class I waters not meeting standards, Class II waters (shellfish harvesting streams), Class II waters not meeting standards, Class III waters (natural trout streams), Class III waters not meeting standards, Class IV waters (recreational trout streams), Class IV waters not meeting standards, oyster beds open to fishing, oyster beds closed to fishing, clam beds open to fishing, clam beds closed to fishing.

(2) Suitability Items:

State and Federally Owned Properties: The size of the parcel, the agency holding title or utilizing the parcel, and the use of the parcel were included for two types of property, State and Federal.

Sewer and Water Service Areas: County sewer and water service plans were combined to indicate the areas presently served by water and sewer as well as the staging for future provisions of these services.

Transportation Facilities: Sixteen separate characteristics were encoded: railroads, gas or pipelines, transmission lines, channel depth (spoil disposal site, 27 feet, 35 feet, 42 feet), intersection of controlled access highway with another controlled access highway (existing, proposed), intersection of controlled access highway with a non-controlled access highway (existing, proposed, combination of two rights-of-way, three rights-of-way), airports and property, rapid rail, and commuter rail.

Historic Sites: The inventory of historic sites provided by the Maryland Historic Trust was transferred to locational maps and incorporated into the data base.

Existing Land Use: Level II land use (U.S.G.S. Bulletin 671) classifications were utilized; these are presently being updated with Level III land use (Appendix A).

(3) Other Items

Watersheds and sub-watersheds: This variable consisted of a map description of all watersheds and sub-watersheds within the State. This variable was used for mapping and analyzing efforts using corresponding statistical data for each of these sub-watershed areas.

Electoral Districts: Electoral districts are large zones used to summarize voting data within the State. Census data and statistical area boundaries nest within electoral districts. This enables data from the 1960 and 1970 Census to be aggregated and used for computer mapping, various forms of analysis, and interface with other data bank variables.

While the primary purpose of the information system was geared to the planning program, it did give opportunity to test the ability of satellite data to carry out the function of updating the information bank.

Data Bank Variables: Two of the most critical requirements of an information system are its viability and longevity. Geographically based information is most deceiving in this respect. At first examination one would anticipate that geographically based data should be limited in scope and stable in content; on the contrary:

(1) urban development is highly dynamic;

(2) natural landscape systems, although not as dynamic as urban systems, are likewise not stable and are subject to change; and

(3) new planning methods developed to cope with regional problems may require new forms of data.

The MAGI system project invested a considerable part of its digitizing efforts in natural resource information which was thought to have a relatively long life span, as well as a host of immediate applications. The variables selected to describe cultural geography are substantially less stable, but also have a number of immediate uses. Because of the possible changing nature of the cultural data (e.g., land use), the system includes maintenance facilities which allow quick and easy modifications to the master geographic files. A central feature of the system is a set of effective procedures and programs for extension and renewal of the data base.

An experiment was conducted to test the capability of ERTS-1 data to carry out the function of updating the MAGI system's master data file. The experiment was to compare an ERTS-1 derived Level I land use map with the MAGI output Level I map to determine whether changes could be detected that would warrant updating the master data file. For the sake of brevity, the experiment focused only on Howard County, Maryland.

A Level I land use map was prepared through manual interpretation techniques from an ERTS image acquired in July, 1973. The original scale of this map, shown in Figure 31, was 1:250,000, ERTS image projection. The MAGI Level I map was originally produced at an approximate scale of 1:211,200, and had an X:Y distortion ratio of 4:5 resulting from the line printer character distortions. Using zoom transfer scope techniques, this distortion was rectified and the scale changed to approximately 1:250,000. The resulting MAGI map is also shown in Figure 31.

The two maps were then compared by visual overlay. Several areas of disagreement were noted which were further compared to a more current (1973) land use map. Efforts were made to determine whether areas of change were correctly detected, or whether disagreements could be attributed to other factors, including erroneous ERTS-1 interpretations, generalizations in the MAGI grid cell coding, differences in map projections and the remedy techniques used, etc.

This analysis pointed out several types of problems in the research method which could not be reconciled and, undoubtedly, influenced the analysis:

(1) comparisons could not be made adequately because identification accuracy from ERTS imagery is not always as good as the accuracy obtained from the high altitude 1970 CARETS source, both with respect to the position of class boundaries and the identification of each mapped cell; and

(2) the interpretable units scales, 10-12 acres for ERTS-1 imagery versus 91 acres for MAGI cells, are basically complementary but unlikely to produce precise boundary accuracies when overlaid.

Although the technique points out where change may have occurred, the problems of technique yet unresolved prevented conclusive results, i.e., the attributing of these changes to the actual process of land use conversion. In this application, the mapping scale from ERTS (10-12 acres) was more than adequate to update MAGI cells (2000' X 2000' or 91 acres).

MAGI

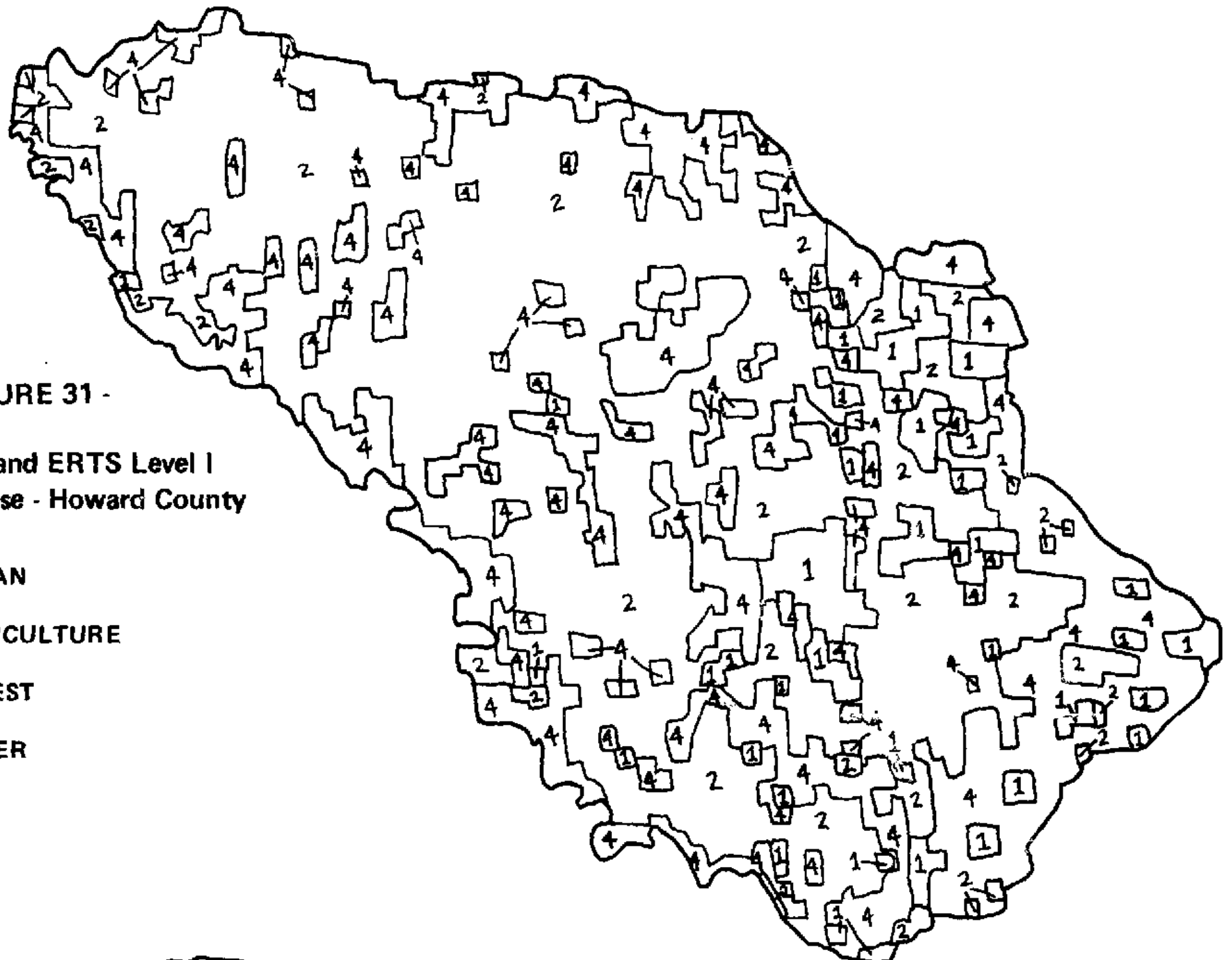


FIGURE 31 -

MAGI and ERTS Level I Land Use - Howard County

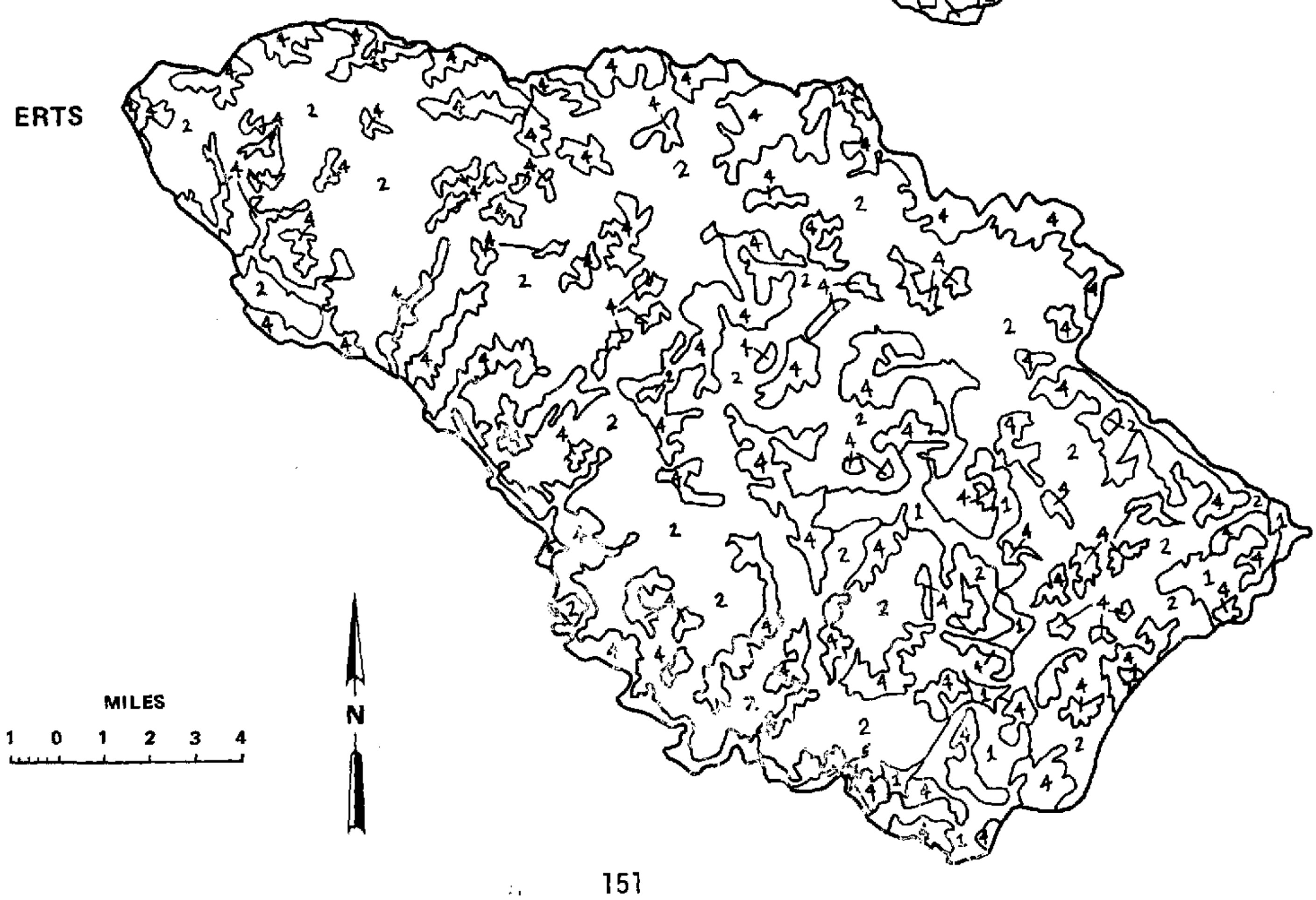
1 URBAN

2 AGRICULTURE

4 FOREST

5 WATER

ERTS



CHAPTER V

ACCEPTANCE AND APPLICATION OF ERTS-1 GENERATED DATA PRODUCTS

The use of aerial photography -- remote sensing -- in land use planning has been extensive since the 1930's only in specialized, not systematic, applications. Until recently, the scope of planning dealt primarily with urban places, their form and function, with particular emphasis on land use regulation and socioeconomic considerations. Resource managers with Federal agencies, especially the U.S. Forest Service and Soil Conservation Service, used aerial photography operationally for some time, but managers and planners of urban places used it very little. The current increase in the use of remote sensing tools has been a result of the broadening of the planner's responsibility and scope of authority which, particularly in environmental issues, has resulted from an increase in the number of significant problems and public interest.

The result has been that land use planning has assumed a more comprehensive view of its responsibilities and has begun to see them in their total perspective. Environmental issues created demands for information and tools to collect and analyze information. Adopting the necessary techniques and methodologies required a learning process, particularly in areas of the United States where attention focused on these issues. In most instances, adopting any innovative concept or tool requires a lengthy process of developing an awareness and interest prior to an equally lengthy period of evaluation and trial, long before adoption is likely. One important function of the NASA ERTS-1 grant to the Maryland Department of State Planning has been to accelerate this process by using the Department's evaluation and trial of ERTS-1 data for building an awareness and interest in other agencies inside and outside the State, as well as providing a basis for refining the system performance requirements.

One of the more significant results of the project has been the development of awareness and interest across all levels, from the Governor of Maryland, the Honorable Marvin Mandel, to local jurisdictions. At the outset of the project, many professionals, elected officials, and users from the public sector not involved in the project were unaware and often openly negative to the idea that "satellite pictures" could be used in an operational planning context. Although the effort needed to insure acceptance of remote sensing as a source of planning information is often overlooked, it became necessary to make education a major element of this project; this was particularly true because the project sought to create a fair test of ERTS-1 data in an operational planning context.

OFFICE OF THE GOVERNOR

The interest and support of this investigation by the Governor of Maryland has been demonstrated both in words and actions. During the investigation the Department of State Planning briefed the Governor on its progress. After reviewing ERTS-1 and aircraft imagery and a variety of materials used in geobase analysis, Governor Mandel initiated efforts to disseminate data and results of the investigation to additional user groups in Maryland. The Governor also directed that an ERTS-1 color mosaic of Maryland be produced and distributed to county jurisdictions. At the Southern Governor's Conference, the Governor strongly encouraged his colleagues to participate in the NASA ERTS-1 program and to manage their own state's resources with these data.

In addition, the Department of State Planning reported on activities, including the ERTS-1 project, to the Maryland Study Commission on Intergovernmental Relations in Land Use Regulation in July, 1973. This group was a joint executive-legislative-citizen group charged by the Governor to study and prepare land use legislation for the State. The report contained a presentation of the Department of State Planning's use of ERTS-1 and high altitude aircraft images for land use inventories, for monitoring of land use changes, and for determining environmental capabilities and suitabilities. The Study Commission was also made aware of the Department's intention to "continue testing of satellite imagery in an effort to demonstrate its applicability to integrated state planning....."

PRODUCTS AND USES BY THE DEPARTMENT OF STATE PLANNING

The results of the experiment can be divided into products, programs, and beneficial experience. The emphasis in this section is on the first two results because they are already evident. Experience is a result that will create more lasting results: continuing experimentation and evaluation leading to further products and programs or abandonment.

The Maryland ERTS Mosaic: The ERTS-1 mosaic of Maryland, initially requested by Governor Mandel, has been used for several purposes. Color mosaics were prepared for distribution to all counties of the State. This action called attention to the sophisticated tools available to the planning community and focused direct attention to NASA's objectives of applying space technology to earth resources studies in Maryland. Two overlays accompanied these maps, showing County boundaries and names and recognizable geographic places such as rivers, mountains, and cities. Enlargements were made to 1:500,000 scale containing the county boundary overlay covering the State, and to 1:300,000 scale for the location overlay, covering each county. Through the Governor the products and results of the projects were readily diffused to all levels of planning in Maryland.

The broad overview of the State's physical environments provided by the ERTS mosaic has led to its application as a communication tool, and for regional and statewide mapping, planning, and resource studies. Prior to the launching of ERTS-1, mosaics could not be compiled as easily because aerial surveys by conventional aircraft could not survey large areas and maintain uniform lighting conditions. The result was that detail and scene contrasts varied substantially.

<u>State and Regional Evaluation and Review</u>: Throughout this investigation regular coordinating and review sessions were conducted by the Department's Investigative Team and other State and regional agencies. Efforts were made to coordinate various activities and share the results of projects which were applicable to varied ongoing State land use planning needs. The activities and results are numerous and will continue in future operational planning programs. Selected examples include:

(1) Several pilot studies have been incorporated into other State agency efforts (e.g. incorporation of marina data into a Department of Natural Resources bay shoreline access study; sewage treatment siting study by the Department of Natural Resources and Department of Health and Mental Hygiene);

(2) Worcester County and Deep Creek Lake shoreline activity was used in a Department of State Planning survey and analysis of recreational developments in Maryland and in access studies;

(3) Ability to identify land use at the third level of the U.S.G.S. classification system led to the expansion of the State classification system and a decision to invest non-NASA funds in a reinventory of the State's land use;

(4) Review comments of regional and local planners of the initial inventory format of the classification scheme used in the temporal analysis of Baltimore and the Baltimore-Washington corridor also led to an expansion of the classification scheme;

(5) Various regional and county land use inventories were directly incorporated into revisions of several county general plans, e.g. Garrett County; and

(6) A variety of natural resource and environmental data required by State and regional planners were provided for their development and planning activities: distribution of forest stands, forest clearings, and insect and disease infestations; distribution of crop and pasture lands; location of open, disturbed, bare, and non-agricultural land.

Several studies have been ready recipients of data and techniques generated from this investigation. A study of growth and development plans and policies applied to the Baltimore-Washington corridor initiated by the State Department of Planning focuses on various determinants of the area's growth capacity, including environmental capacity, existing and proposed services and facilities, and institutional characteristics. Participating in the study are the State, the City of Laurel, the Counties of Anne Arundel, Howard, Montgomery, and Prince Georges, and the Maryland National Capital Park and Planning Commission.

The first phase of the study consists of a series of maps and narratives dealing with alternative growth and development policies with the greatest applicability to the study area. Conclusions of the study will be presented to the elected and executive officials of each jurisdiction for their own review and discussion with the public and their own planning agencies. This report will be used as a first step toward the adoption of development policies for the corridor as a specialized region, and for the possible modification of existing land use policies by local jurisdictions.

A study of prime agricultural land has been mandated by the Maryland legislature to be conducted by the Department of Agriculture which, in response, has used land use and natural soil group data, and the capabilities of the MAGI models.

Collection of original data: A large amount of photographic data has been collected for the Maryland Department of State Planning and other NASA investigators that consists of high altitude ERTS-1 underflight photography acquired by the National Aeronautics and Space Administration's RB-57 and U-2 aircraft. This collection has been cataloged for use by State and regional planners and other researchers. A document, the "Maryland Aerial Photography Catalog" contains plot maps of photography for each mission. This catalog provides an atlas guide and reference of photographic coverage for selection and retrieval. Users of this catalog may select photography over areas of interest and request the imagery from the Department of State Planning film library. The Catalog includes:

(1) clear and descriptive information for each mission as summarized from Flight Summary Reports and other documents;

(2) a detailed inventory of coverage for missions between 1969 and 1973; and

(3) means of locating and classifying all available photography for any area under investigation within the State of Maryland.

Figure 32 is a sample page from the Catalog. Similar sheets were produced for each mission and distributed to user groups.

ERTS-1 imagery was also indexed for retrieval and use. Imagery were provided to the Investigators on a standing order basis. Upon receipt of these materials, principally 70 mm negatives and 9 X 9 inch positive transparencies and prints, they were indexed for subsequent retrieval. ERTS-1 70 mm negatives were separated from other products to better insure their safety, and indexed and filed by sequential frame numbers. When negatives were required for reproduction purposes, they could be identified by frame numbers. This method was found to be the most simple and efficient filing system.

Film positive (1:1,000,000) transparencies were filed by sequential date as a sub-category of the orbital tracks (seven tracks cover Maryland). By separating orbital tracks, identifying and finding imagery over a particular region was easier. Because of the westward shift of the orbital tract, two files were referred to on several occasions, especially when comparisons were desired of images separated by many months.

A card file was maintained on all imagery received for Maryland. This file contains a brief description of the scene location, unique observations, and a description of image quality -- Excellent, Usable, Unusable -- defined as follows:

(1) Unusable: Atmospheric conditions (cloud and haze) either preclude specific location of the scene, or diminish shapes, patterns, and contrasts among grey tones to the degree that no additional information is provided over previous images.

(2) Usable: Specific locations can be confirmed; shapes, patterns, and grey tones are sufficient to identify landforms and cultural features; all the above information contributes to a net gain in information over previous imagery.

(3) Excellent: All the usable conditions, slight atmospherics, a broad range in grey tones, and specific cultural features are identifiable; angular shapes and patterns are crisp.

The number of images in each category have been tabulated by season for imagery received between August, 1972 and June, 1974 (Table 10). Imagery rated as excellent are included in the enclosed Image Descriptor Forms. (Appendix B).

APPLICATIONS OUTSIDE THE DEPARTMENT OF STATE PLANNING

The Comprehensive State Planning Division, the sponsoring agency of the ERTS-1 experiment and the MAGI system, expects data from both projects to be used in a wide range of planning, coordination, and evaluation activities. The data base can provide meaningful input into the following efforts:

(1) review of wetland activity permits;

(2) review of county water and sewer plans and their impacts on land use;

(3) open space and recreation planning including the implementation and acquisition phase of the State recreation plan;

(4) other miscellaneous environmental analysis reviews;

(5) participation in the multi-modal transportation planning process;

(6) specialized studies, e.g. joint State and Federal (Atomic Energy Commission) study for power plant siting;

(7) preparation and review of the State's Annual Capital Budget, functioning as the State Clearinghouse for Federally-funded projects (A-95 review).

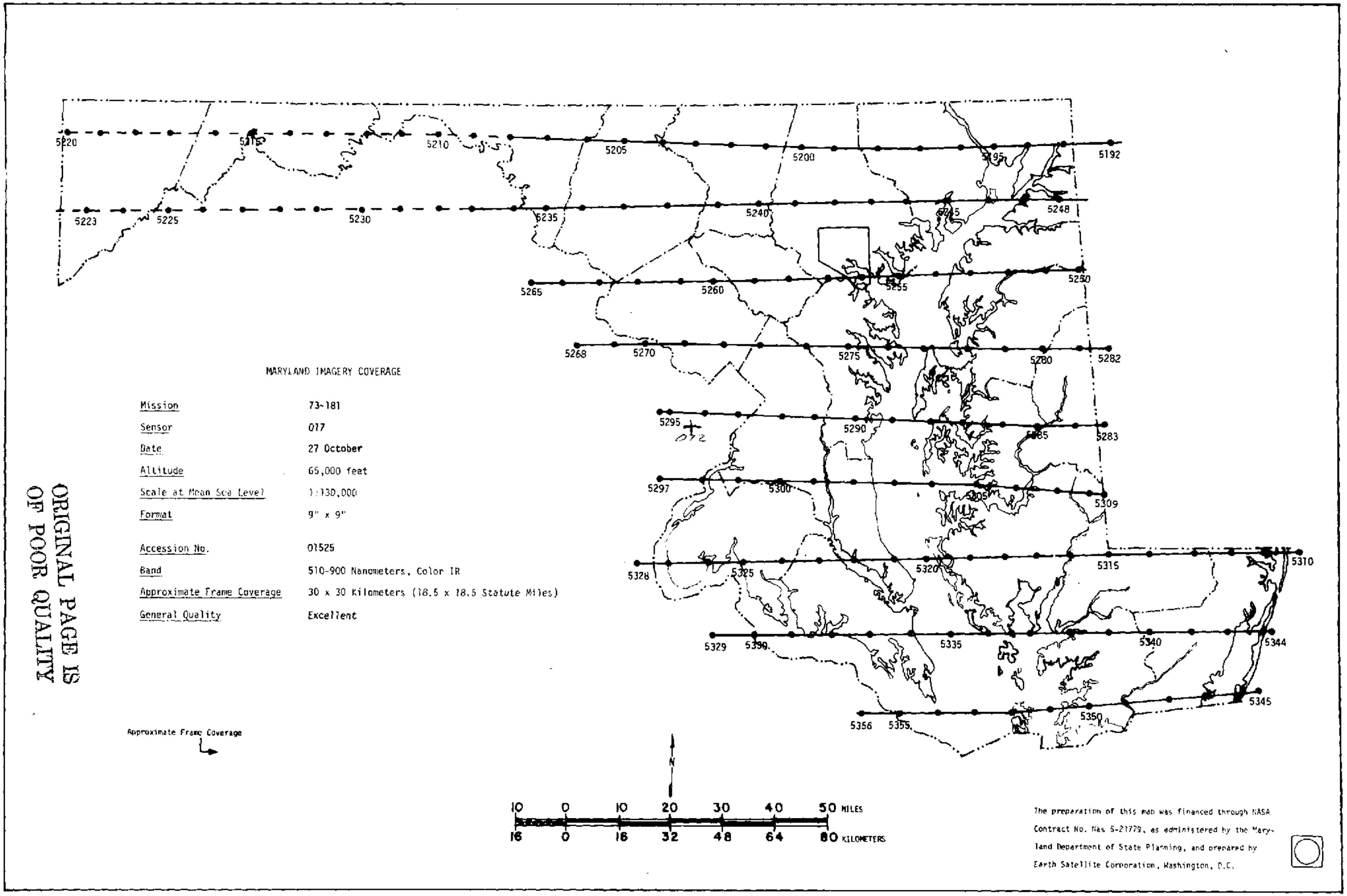


FIGURE 32: Sample Page from Maryland Photo Index

QUALITY OF ERTS-1 IMAGERY OF MARYLAND

TABLE 10

YEAR	SEASON*	EXCELLENT	USABLE	UNUSABLE**	TOTAL
1972	Summer		1	1	2
	Fall	9	6	1	16
1972-73	Winter	3	13		16
	Spring	5	10		15
	Summer	7	9	3	19
	Fall	1	6		7
1973-74	Winter	5	6		11
	Spring	1	7	1	9
	Summer		3	1	4
	Total Summer	7	13	5	25
	Total Fall	10	12	1	23
	Total Winter	8	19		27
	Total Spring	6	17	1	24
	Total	31	61	7	99

* Summer (J,J,A), Fall (S,O,N), Winter (D,J,F), Spring (M,A,M)

** Imagery with greater than 30% cloud cover was not requested and therefore, not included in this table.

Much of the data has applicability to the Departments of Transportation, Health, General Services, and Natural Resources (e.g. Federal Coastal Zone Management Act). The data embodied in the MAGI system can serve as a general data base capable of integrating additional special purpose information with the original data variables.

The State Legislature often seeks information from the Department of State Planning to support various legislative studies or committees. The ability to retrieve multi-dimensional data with short turnaround time will enable the Department to react in a more efficient and timely manner.

Many of the counties and towns in the State do not maintain a sufficient level of planning and evaluation data, and those counties and towns which do collect data rarely do so in a coordinated manner. Because of the continuous nature of the data collected, the MAGI system offers two additional opportunities: (1) to make data available to jurisdiction "A" concerning jurisdiction "B", where "A" might be affected or impacted by the events of "B," and (2) to provide data about jurisdictions "A", "B", and "C" so that they can be compared.

In recent years citizen organizations and unaffiliated individuals have sought and gained increasing participation in the governmental decision-making process. This participation has become more sophisticated; from voicing general objections or support, citizens now bring forth their positions with legal and technical support. In this advisory role the citizen groups and individuals have become both users and reviewers of government data. The MAGI system will permit the Department to interact with and support these groups in a more timely, complete, and efficient manner.

Private industry, particularly the development sector, having been affected more frequently by governmental actions (e.g. sewer moratoria, environmental impact reports, etc.), have become more sensitive to governmental activities, particularly those related to the environment. Potentially, conflicts can be minimized by making basic data available to the private sector and thereby working with a common data base; it is also possible that increased communication and understanding may be achieved.

The diffusion of data through all these groups is most likely to occur from the planning agency through allied agencies and other State, local, citizen, and private groups in order of their professional contact with the Department of State Planning. In theory, better data makes better decisions and the responsibility of the data holder is to disperse, not retain.

CHAPTER VI

SIGNIFICANT RESULTS AND CONCLUSIONS

An experiment to use remote sensing data in land use planning faced one major difficulty from the outset - the widely accepted fact that land use planning is primarily a function of local governmental institutions. Although conventional remote sensors are widely accepted (e.g. black and white photography), their acceptance came slowly and it was likely that more sophisticated techniques would present a far more difficult task of building credibility and demonstrating significant advantages.

More rapid acceptance is likely when the institution is forced to change and changes rapidly. This experiment focused on one such institution, the Maryland Department of State Planning, which responds to current demands for planning that is environmentally sensitive and responsible and evaluates all available methods for that task. Remote sensing gained an audience and an evaluation in a practical test across a range of users -- state, county, local -- through applications which were designed, tried, and evaluated. Documentation of these trials, presented in Chapter IV, is summarized in this chapter in two major parts: (1) a general evaluation of ERTS data as a source of planning information, including the characteristics of this information which give its value, its role in present and future statewide land use planning, and its cost advantages compared to other remotely sensed data; and (2) an evaluation of sensor performance comparing ERTS with conventional remote sensors in a variety of tasks specified by State planners.

Characteristics of Information of Value

Information generated from ERTS-1 data has two main types of value to planners which create a demand for its utilization: characteristics which enable ERTS-1 data to be substituted for existing data sources; and characteristics which introduce new or incremental capabilities and applications which existing sources are incapable of providing.

Substitution Capabilities: ERTS-1 data is a potential substitute source for statewide and regional data acquired by land use planners by conventional means. It has the capability to substitute for conventionally generated Level I and II land use, and partially Level II data now used as inputs to the production of maps, overlays, geobased information systems, computer simulation models, and statistical data. From a functional perspective, ERTS-1 data can be applied to accomplish the following functions which are presently performed by conventional aerial and ground surveys:

- Initial Area Coverage

  In many unmapped regions of the United States, the availability of ERTS-1 data at a reasonable cost enables the planner to obtain an initial overview of land use activities and types of land cover. This is particularly advantageous if the area of interest is remote and without recent map coverage, including topographic sheets. A user in this instance may utilize ERTS-1 data in the form of a photomosaic as an updated map for cultural information, or as a special purpose map for land use and land capability analyses.

- Periodic Update

  The repetitive coverage and synoptic view provided by ERTS-1 make it an effective and systematic tool to update Levels I and II land use and land capability inventories and, secondly, to obtain an overview of areas of change or critical areas requiring more detailed inventory and analysis.

- Monitor of Surface Conditions

  ERTS-1 is well-suited to perform monitoring of point sources and general surveillance over large geographic areas for purposes of management and regulation, e.g. illegal lake drainage or strip mine reclamation.

Land use planners presently employ many types of sources to perform these functions, both primary and secondary sources. Primary sources include contracting for commercial surveys, performing field and windshield surveys and, in some cases, distributing questionnaires. Planning agencies commonly do not possess the funds necessary to directly obtain all primary source information. In these situations, extensive use is made of secondary sources, including previously acquired aerial photography and ground data, data collected in less specific form by other state agencies, and the array of statistical and cartographic information produced by the U.S. Bureau of the Census and the U.S. Geological Survey.

Although ERTS-1 data is considered a substitute source of data, it is distinctive and technically different from information produced from conventional sources. The major difference is that ERTS provides new and incremental capabilities for planners, for example, repetitiveness of information. However, some of these differences are in the type of substitute information generated from ERTS-1 data, i.e. the resolution and uniformity of data.

ERTS-1 data is characterized by increased granularity, a high level of aggregation, and an increased uniformity associated with its synoptic view. Conventional data is normally less granular but with an off-setting lower uniformity due to its multi-source contents. The high level of aggregation of ERTS-1 data provides a uniform product to be utilized at higher and broader jurisdictional levels without necessitating the expensive process of aggregating detailed data from varying sources. Due to the inclusion of fewer variables in the process of developing aggregated data, the resulting product is more uniform and standardized in all aspects, and often more accurate. The impact of these characteristics is significant in light of the growing involvement of broader and higher jurisdictional levels such as state and regional governments in land use planning. ERTS-1 provides state planners with a direct source of timely and current data that enables them to better appreciate, compare, and coordinate the activities of the lower jurisdictions. It also provides a superior discrimination mechanism with which to identify and delimit areas requiring additional analyses. The increased uniformity of information combined with the capacity for continuous, repetitive monitoring develops an improved and standardized basis upon which the state or regional planner can base his decisions.

It is important to recognize that the lack of uniformity in conventionally generated products can be lessened at the large expense of acquiring data via comprehensive aerial surveys. States which either have or are capable of financing such collection programs (e.g. New York and Minnesota) are limited in number. Although the larger scale conventonal data still must be aggregated to provide the synoptic view of ERTS-1, the compromise of uniformity is significantly less than in the more typical state where sources consist of an agglomeration of non-standardized data. In comparison to ERTS-1, data from conventional aerial sources provide such large amounts of detail that the image may be reinterpreted several times for various purposes. However, unless continuing funds are provided the photography will not provide the necessary comprehensiveness, repetitiveness, and timeliness possible with ERTS-1 data. The planner will thus be limited to outdated sporadic information, the traditional form that results from conventional data acquisition techniques.

<u>Incremental Capabilities</u>: ERTS-1 data also provides a means for planners to realize benefits in the planning process and its outcomes from the new or incremental capabilities associated with ERTS-1 data. These capabilities include:

- <u>Catalytic Impact</u>

  State and regional jurisdictions may take the initial step in developing operational land inventory programs now that data can be provided economically, and are available, flexible, and easy to use. In addition, the initial inventory may be combined with increased systematic and repetitive monitoring and updating over a larger area of collection. As a secondary effect, use may increase of modeling, automated environmental impact evaluations and other quantitative data techniques. The overall effect of the ERTS-1 catalyst is to involve an increasing number of planning agencies and other state users who find advantages of inexpensive ERTS-1 data that enables them to initiate and maintain a continuous land use monitoring, planning, and management program.

- <u>Time Dimension</u>

  The repetitive coverage frequency inherent in ERTS-1 provides the planner with an increased and sometimes new "time dimension" for land planning and environmental analyses. As compared to the infrequency of conventional surveys, ERTS-1 data provides a refined time dimension capable of making areal comparisons on the basis of seasonal change among physical and cultural patterns, particularly in areas dominated by highly dynamic activities, e.g. the coastal zone and urban fringe. This capability provides a highly comprehensive and systematic historical record of activities and conditions upon which to base future land use plans.

- <u>Uniformity and Standardization</u>

  ERTS-1 data provide a better basis for standardizing observations over large geographic areas and providing greater uniformity than conventional sources of information.

A common time period and a common set of technical parameters provide this uniformity. The effect is that phenomenological comparisons, e.g. land use patterns, may be more valid and the overall product more reliable. Much of the existing land use data are developed from multi-source data varying geographically in terms of acquisition data, scale, classification system, resolution, accuracy requirement and general technical uniformity. These variables create problems and limitations in areal comparative analyses, comparisons which are important to state, regional, and local planners. The state planner requires common data over large portions of the state. The regional planner is concerned with environmental conditions and developments in surrounding jurisdictions and the effect they may have on his own area of responsibility.

- Communication Capacity

A subtle but significant incremental benefit is obtained in public planning meetings simply due to the availability of ERTS-1 pictorial data in enlarged or mosaic forms. ERTS-1 data ease the communication of environmental information among the state's technical community, as well as among legislators and the public. This is particularly important among state planners since they are commonly coordinators of activities among other functional agencies and prime points of interface with the public. The ease of communicating information with ERTS-1 data facilitates development of an awareness of the importance and implications of environmental issues, e.g. land use planning and management. ERTS-1 has been demonstrated as a powerful tool for affecting public opinion.

- Quick Look

ERTS-1 enlargements and mosaics are extremely useful for "quick look" analyses and references by a variety of users including technical individuals and legislators. The mosaics, which are normally used as updated resource maps for reference and presentation, result in subtle improvements in resource awareness and subsequent processes of decision-making. As an example, the use of ERTS-1 data as a presentation/communication media in the legislative process that resulted in the New Jersey Coastal Zone Protection Act has significant benefit implications.

- Targeting

  The synoptic and periodic capabilities of ERTS-1 are well-suited for providing a generalized update of surface conditions and for targeting or pinpointing areas of rapid change that might require further analysis. Cost savings may be achieved through delineating areas with ERTS-1, then employing detailed aircraft or ground survey techniques, more effectively. The "targeting" advantages of ERTS-1 also provides a preview of the significant features of the area of interest, and thus aids in optimizing the proper coverage of the area of interest by conventional means.

  Without the comprehensive "targeting" function of ERTS, the planner is forced to rely on more sporadic, segmented, and nonstandardized conventional sources for determining rates of land use change of different areas. This could result in critical areas or regions of high rates of change being undetected. If detection of such areas was required, conventional surveys would require a signficant allocation of funds for large scale surveillance either by aerial or ground survey.

- Data Organization

  The ability to adjust scales and to integrate the use of ERTS-1 data with supplemental multistage imagery offers ease of organization and reference involving the national, multistate, state, regional, and local jurisdictions. Ohio, for example, recognizes ERTS data as a means of providing an information organizational structure which may be used to encompass and organize existing data and fill in gaps in classes of data previously developed.

- Flexibility

  The flexibility inherent in all aspects of ERTS-1 usage make it an attractive data source to a multitude of disciplines. In addition to the flexibility of processing and interpretation, high compatibility of ERTS with computer processes provides a significant area of application. This compatibility exists with automatic processing techniques, information systems, automated simulation, and general statistical manipulation. The spatially oriented character of ERTS data requires less transformation for purposes of geocoding or general utility and communcations.

- Timeliness

  The signficance of timeliness is vast and represents a new capability for state and regional planners that is particularly important. One of the major advantages of ERTS is its ability to monitor, periodically and frequently, the cultural and physical patterns of a large area. Although it is theoretically possible, given the required fiscal, human and equipment resources, to duplicate the timeliness of ERTS data, it is not likely to become an operational reality. The timely nature of ERTS is even more significant in light of the increased rate of environmental change and the necessity for decisions to be made within a continually dwindling time frame.

- Spectral Signatures

  New "spectral manifestations of the environment" are provided planners by the ability of ERTS to sense and extract spectral differences which can be enhanced by a variety of interpretive equipment, e.g. density slicers. Although the full implication of these spectral data to the planning community is still being explored, the opportunity to use a different form of information describing the physical and cultural landscape may contribute to a new analytical capability to the planner.

ERTS-1 CONTRIBUTIONS IN PRESENT AND FUTURE STATE LAND USE PLANNING

The nature of planning operations today and in the future structures the demand for information and gives expectations of the role of ERTS-1 data. An historical analysis of the scope of planning shows it reflects changing public priorities; a series of demands have been made on planners that have built the present structure of planning (e.g. attention to the physical structure of cities, capital budgeting and programming, social and economic issues). Attention has centered where concern was greatest, at the level of urban places. Two changes are bringing about additional functions and changes in the level of activity: the environmental interest and the rising importance of planning at higher jurisdictional levels. These changes reflect public priorities (e.g. land use and environmental legislation) based on a more comprehensive and integrated understanding of the nature of the problem and the level at which improvement may be obtained. Changes focus at the highest jurisdictional level, the state, where the greatest likelihood for solutions lies; this has placed state planning agencies in a state of flux.

The impact has been to place a demand on earth resources information and a means of collecting and handling the data on a statewide scale. States in the "amenity areas" (seacoasts, mountains) and urban states have already made substantial progress in developing the necessary techniques. Until recently the state was not likely to collect such data. Adapting to the demand for environmental information faces considerable inertia because of the need to develop new analytical methods, as well as to solve the problem of data collection and manipulation. In this area, planners find it particularly difficult to accept unproven techniques. Acceptance of any technique thus depends on its relative advantage over other techniques in terms of accuracy, reliability, credibility, and cost-effectiveness.

ERTS-1 data has substantial advantages as a means of data collection either as a substitute for other data sources or as a means with new incremental capabilities. The greatest advantage using ERTS-1 information will be among those who require it as a primary source of information and as a means of updating detailed information banks.

ERTS-1 As a Primary Data Collector: Three scenarios were presented in Chapter IV which identify the general role of ERTS-1 data in supplying land use/cover information: major, contributing, and minor roles. The application of ERTS-1 as a primary data collector rather than as a targeting or change detection device consists of its ability to collect all Level I and most Level II categories of land use/cover information used in statewide and regional scales of planning.

The most important application for this type of information is to portray information over large areas where high levels of detail are not essential and which, perhaps, might prove confusing. Prior to ERTS-1, information was often aggregated from lower jurisdictions, irrespective of the timing and quality of those sources. Heretofore, there has been no means of acquiring these data directly from one source.

Such information is used commonly to formulate and develop overall concepts and plans for the larger jurisdiction. These plans require support for coordination among lower jurisdictions and line agencies to be effective. A basic task of the state planner is to monitor activities for consistency with the comprehensive plan. In this capacity, the statewide plan and the state planner must be able to generate support and confidence. One essential task in building support is to communicate the need for the plan; another is to provide information including comparative data.

In this regard, the ERTS-1 image and a series of themes mapped from the image have a considerable importance as a communication device. A common format is the "one-half million" scale (1:500,000) which typically is used for large regions and states. The resolution of primary data collectors need not be fine because the general character of information does not require knowledge of its individual bits. Therefore, the unit of data collection (cell size) can be large. Capability must be equal at this scale to recognizing first and second level land use/cover information. An appropriate cell size for 1:500,000 scale can be units of 2,000' X 2,000'.

An important distinction must be made at this level of planning that places information accuracy into the proper context. What is considered accurate relates to the information content of the data, not necessarily to its accuracy by some fixed standard such as the number of data bits identified. If land use change by itself is an objective of planning data acquisition, then information concerning changes and accurate change detection are sufficient tasks for a collection system and more important than the identification of the nature of change itself. If these objectives were met without aggregating large volumes of detailed information, the advantages of the one system over the traditional aggregation system would be obvious.

ERTS-1 as a Means of Updating Information Banks: Many state planners, like state legislators, anticipated future planning trends and built information systems and planning models to facilitate operations. In modernizing information handling and preparing for forecasting, they have created greater demands for data, particularly current data, than otherwise would be the case with or without legislation. Many information systems are built around environmental data, because of its ease of collection and presentation (it can be rectified to grid systems whereas socioeconomic data is generally oriented to parcels which are small and irregular).

An important conception in the environmental system is that it lends itself to modeling, suitability and capability analyses, or other combinations of information that relate data systematically according to a purpose and create new information. Relationships between elements of the landscape are key to modeling, suitability and capability analysis, and to evaluating trade-offs between environmental choices planners must make.

The proper operation of the information system and environmental models thus depends on a systematic maintenance program involving periodic monitoring of all phenomena and updates of dynamic features. With this method of operation and maintenance, the system becomes a recursive device that helps formulate environmental policy, monitor its effects, and provide these data for subsequent policy formation. ERTS-1 data may contribute to updating models primarily in a targeting or change detection mode by determining how extensive and where updating is needed.

The advantage of ERTS-1 data vis a vis conventional data collectors mainly consists of cost-effectiveness in compiling Level I land use maps and in deploying conventional collectors in larger scale studies of small geographic areas, e.g. studies of critical problems and updating areas of change. Cost comparisons are made in the following section between ERTS data and conventional data in similar applications.

Cost Comparisons for Various Sources of Planning Data

Cost estimates to acquire, interpret, and render cartographically spatial information derived from ERTS-1 data were generated from two sources: a synthesis of ERTS-1 experiment results provided by investigators across the nation who attempted to obtain land use information and corporate experience by Earth Satellite Corporation (in every case the actual cost estimate is keyed to one or more representative projects). These costs were based on the use of a variety of manual techniques and remotely sensed data. Costs associated with these systems have been developed for each level of land use information in the U.S.G.S. classification system. More detailed levels of land use information have been obtained more directly from conventional techniques. For example, Level III data collection cannot be obtained from ERTS-1 directly, with its present resolution capabilities, but conventional surveys can be made more efficient with ERTS-1 data in determining where and if such data collection should be made.

Costs have also been developed for commercially available conventional photography. These costs are presented on Table 11 in a manner that allows data collection costs with and without ERTS-1 involved. With ERTS-1 involved, costs are divided into varying proportions of ERTS-1 data combined with other data. Consequently, there are two basic types of Tables:

(1) Costs With ERTS-1 Data

Level I - Independent ERTS
Level II - ERTS with Multi-Staged Surveys and Sampling

TABLE 11

MANUAL INFORMATION EXTRACTION COST ESTIMATES

COST FACTORS	COST FACTOR DATA	COST FACTOR DATA	COST FACTOR DATA	COST FACTOR DATA
	Level I ERTS System	Level I Without System	Level II ERTS System	Level II Without System
Information Type	Land Use	Land Use	Land Use	Land Use
Information Detail	Equiv. to Anderson '72 Level I, or Poulton's '72 Primary Classes	Same as Level I ERTS	Equiv. to most of Anderson's '72 Level II Categories or Poulton's Secondary Classes	Same as Level II ERTS
Scale	1:250,000 to 1:500,000	Same as Level I ERTS	1:63,360 to 1:250,000	Same as Level II ERTS
Product Format	Line Overlay with Legend and Title	Same as Level I ERTS	Line Overlay with Legend and Title	Same as Level II ERTS
Interpretation/Data Handling Costs				
@$15.00/hr	$0.203/sq. mi. to $0.246/sq. mi.	$0.646/sq. mi. to $0.783/sq. mi.	$0.356/sq. mi. to $0.431/sq. mi.	$1.085/sq. mi. to $1.327/sq. mi.
Cartographic Time				
@$10.00/hr	$0.136/sq. mi. to $0.164/sq. mi.	$0.432/sq. mi. to $0.523/sq. mi.	$0.238/sq. mi. to $0.288/sq. mi.	$0.634/sq. mi. to $0.767/sq. mi.
Photo-Image Acquisition and Processing Cost/p sq. mi.	$0.007/sq. mi.	$3.80/sq. mi.	$0.007/sq. mi.	$3.80/sq. mi.
TOTAL COSTS	$0.346/sq. mi. to $0.417/sq. mi.	$4.878/sq. mi. to $5.106/sq. mi.	$0.601/sq. mi. to $0.726/sq. mi.	$5.519/sq. mi. to $5.895/sq. mi.

TABLE II Cont'd

COST FACTORS	COST FACTOR DATA	COST FACTOR DATA	COST FACTOR DATA	COST FACTOR DATA
	Level II ERTS/Multi-Approach	Level II Without System	Level III ERTS System	Level III Without System
Information Type	Land Use	Land Use	Land Use	Land Use
Information Detail	Level II (Anderson) '72 complete	All of Anderson's '72 Level II Categories or Poulton's '72 Secondary Classes	Equiv. to Poulton's '72 Tertiary Classes	Same as Level III ERTS
Scale	1:63,360 to 1:250,000	Same as Level II ERTS	1:24,000 to 1:63,360	1:12,000 to 1:40,000
Product Format	Line Overlay with Legend and Title	Same as Level II ERTS	Line Overlay with Legend and Title	Same as Level III ERTS
Interpretation/ Data Handling Costs				
@$15.00/hr	$0.855/sq. mi. to $1.035/sq. mi.	$0.891/sq. mi. to $1.079/sq. mi.	$1.781/sq. mi. to $2.156/sq. mi.	$5.496/sq. mi. to $6.653/sq. mi.
Cartographic Time				
@$10.00/hr	$0.432/sq. mi. to $0.523/sq. mi.	$0.594/sq. mi. to $0.719/sq. mi.	$1.188/sq. mi. to $1.438/sq. mi.	$2.714/sq. mi. to $3.286/sq. mi.
Photo/Image Acquisition and Processing Cost/ sq. mi.	$0.267/sq. mi.	$3.80/sq. mi.	$3.80/sq. mi.	$6.00/sq. mi.
TOTAL COSTS	$1.554/sq. mi. to $1.825/sq. mi.	$5.285/sq. mi. to $5.598/sq. mi.	$6.769/sq. mi. to $7.394/sq. mi.	$14.21/sq. mi. to $15.94/sq. mi.

(2) Costs Without ERTS Data
Level I
Level II
Level III

Representative costs of data extracted by automated techniques could not be developed from ERTS-1 experiment results and, for this reason, are not presented. Costs representative of differences in interpretability, e.g. geographic areas where land use categories are easier to identify, have not been presented due to the absence of sufficient samples.

The tabular format used to present cost estimates contains three columns. The first contains a list of items upon which costs are based: information type and detail, scale, etc. The second column contains cost estimates in terms of square miles interpreted per hour (wherever possible), and cost per square mile. The third presents references (abbreviated) to the sources of these figures.

All cost figures have been organized to represent an average based on commercial burdened rates throughout the nation. Since estimates are based on results obtained primarily in research situations and by individuals experienced in these technologies, the reported rates are likely to be equaled only in certain very favorable commercial or governmental circumstances. For example, interpretation time varies as a function of the familiarity of the interpreter with the region and his skill; cartographic time varies with the method of representation (line drawing, scribing, etc.). Corporate experience has shown that skilled interpreters will gain familiarity and identify features at the same rate as cartographers can prepare and portray land use patterns in line drawings. Consequently, both steps, interpretation and representation, have been assumed to require equal time. Photo-Image acquisition costs are based on prices for standard photographic products published by the EROS Data Center and commercial estimates for enlargement to mapping scale.

Cost is only one criterion used to determine which remote sensor will be utilized. The general capabilities of ERTS-1, both substitute and new capabilities demonstrated in practical use in the Maryland statewide planning program, identify the areas and extent of ERTS-1 usage.

MEASURES OF PROJECT SUCCESS

This project was initially designed to test remote sensing as an information source in statewide land use planning, emphasizing ERTS-1 as the primary sensing system. Theoretically, the structure of such a project involves a comparison of the ERTS-1 system capabilities (supply) with the planner's need for information (demand) that identifies areas of overlap that constitute potential applications which are then tested and evaluated.

A "realistic" setting for experimentation, however, tends to select only those potential application areas that show higher degrees of promise. Emphasis on promising applications is due to the need to separate experimental objectives from objectives of the planning program to minimize interference, distraction, etc. Therefore, the reporting procedure in this summary is structured around a set of planning information needs amenable to solutions by remote sensing. ERTS and conventional remote sensors are evaluated in a competitive situation in each of these tasks. Some tasks were undertaken solely by conventional sensors without experimentation with ERTS data; others used a combination of ERTS and conventional techniques; and in some, ERTS played a major role (Table 12).

The value of information is basically measured by its use, the importance of that use, and the difficulty of obtaining substitute information. New or incremental information, however, cannot be evaluated on these bases. Several applications of ERTS data fall into the category of new or incremental information: Level I land use maps, statewide geologic fracture maps, and tools to monitor and detect changes. Both new and substitute capabilities were demonstrated in the project and contributed to the planning program. Having defined these terms and summarized ERTS capabilities by experiment, the overall project can be evaluated on the following three bases:

(1) whether it met its original objectives;

(2) whether the research demonstrated practical applications; and

(3) whether the results and methods were positive influences on existing procedures.

Meeting Original Objectives

The original objectives of the project (Chapter II) focused on practical, rather than experimental applications of remote sensing data. These are, by definition, primarily applications where ERTS data substitutes for conventional data rather than establishes new

TABLE 12

CAPABILITY OF ERTS AND CONVENTIONAL REMOTE SENSORS IN VARIOUS PLANNING TASKS IN MARYLAND

Application	ERTS Capability	Conventional (high-altitude aircraft) System Capability
Land Use Mapping		
Level I	1	3
Level II	1*	1
Level III	3*	1
Special Studies		
Marinas	3	1
Shoreline development	3	1
Recreational development	3,2*	1
Urban change detection	3,2*	1
Suburban change detection	2,2*	1
Bare ground analysis	1,4	3* (insufficient timely images)
Forest mapping	2	1
Forest defoliation	2,4	1* (special flights required)
Regional geologic lineaments	1,1*	2*
Water quality	2	1 (special flights required)
Land Capability and Suitability Analysis		
Supply basic data	3	2 (mixed data used, some imagery)
Maintain data base	4	4

LEGEND:

(1) major
(2) minor
(3) little or no capability
(4) requires additional research
(*) determined from research literature

applications and offers new and unique information. Table 13 classifies remote sensing techniques, conventional and ERTS, according to their ability to provide information that satisfies the basic objectives of the project. These capabilities are based on the original set of tasks chosen for analysis by the Department of State Planning.

Demonstrating Practical Applications of Research

The project design initially set down four requirements that all research performed within the combined planning program-experiment must meet. These requirements were designed to insure that the use of all remote sensors, conventional as well as ERTS, would be oriented toward practical, realistic problems rather than purely experimental problems. These four requirements are the basis for evaluating each system as it was applied to the various tasks of the Maryland statewide planning program (Table 14).

Influencing Data Acquisition Methods of the Maryland Department of State Planning

Accomplishments in data acquisition by remote sensing have influenced four programs and projects: (1) recommendation of the continuance of the high altitude photography coverage; (2) creation of a centralized data file with mandatory use requirements; (3) development of an historic land use study; and (4) development of a Level III land use map.

The total impact of remote sensing's contributions to the Maryland general planning program can be summed up by the recommendation to NASA suggesting that the high altitude aircraft program be continued. Aircraft data were determined to have the highest utility, widest applications, and most direct use in planning programs, including programs of other agencies.

Another program which came out of the ERTS-1/remote sensing experiment was the creation of a substantial data file at the State level consisting of imagery, maps and tables, digital tapes, and information collected from a multitude of sources and stored in the computerized information system (MAGI). One major reason for developing this repository at the State planning level is that the State, traditionally, has been a disseminator of funds for special planning studies and data.

TABLE 13

ERTS VERSUS CONVENTIONAL REMOTE SENSING
MEETING OBJECTIVES OF THE PLANNING PROGRAM

Planning Objectives:
A. Assess physical, economic, and social resources
B. Formulate cogent development and growth policies
C. Monitor resultant development trends
D. Provide a continuing, dynamic planning information base

Application	ERTS-1 System	Conventional (high altitude aircraft) System
Land Use Mapping		
Level I	2	3
Level II	2	1
Level III	3	1
Special Studies		
Marinas	3	1
Shoreline development	3	1
Recreational development	3	1
Urban change detection	3	2
Suburban change detection	2	1
Bare ground analysis	1	3
Forest mapping	2	1
Forest defoliation	2	2
Regional geologic lineaments	1	2
Water quality	2	2*
Land Capability and Suitability Analysis		
Supply basic data	3	2
Maintain data base	4	4

LEGEND:

Capabilities= (1) major,
(2) minor,
(3) little or no capability,
(4) requires additional research,
(*) determined from research literature.

TABLE 14

ERTS VERSUS CONVENTIONAL REMOTE SENSING
MEETING REQUIREMENTS FOR ADOPTING NEW TECHNOLOGY*

Requirements for adopting new technology:

(A) Contribution to operational programs
(B) Link with existing institutions and human models
(C) Communicability outside original application
(D) Basis for continuing research and potential application

Application	ERTS-1 System	Conventional (high altitude aircraft) System
Land Use Mapping		
Level I	1	2
Level II	2	1
Level III	3	1
Special Studies		
Marinas	3	1
Shoreline development	3	1
Recreational development	2	1
Urban change detection	3	1
Suburban change detection	2	1
Bare ground analysis	1	2
Forest mapping	2	1
Forest defoliation	2	1*
Regional geologic lineaments	1	2
Water quality	2	1
Land Capability and Suitability Analysis		
Supply base data	3	2
Maintain data base	4	4

LEGEND:

Capabilities = (1) major,
(2) minor,
(3) little or no capability,
(4) requires additional research,
(*) determined from research literature.

Importance has also been demonstrated of the value of historic land use information in identifying growth trends and rates. Studies of historic land use patterns financed by State sources were conducted within the bounds of the general planning program.

Development of a Level III land use map for the entire State was another project conducted within the greater project. The State Planning Department's role as a disseminator of data required them to develop information that served the most common type of use, or had the highest general utility. Since county and local agency planners found higher detail more useful, funds were provided by the State to develop a statewide Level III land use map.

Appendices

APPENDIX A

1973 LAND USE CLASSIFICATION SCHEME DEFINITIONS

INTRODUCTION

The Land Use Classification Scheme for the detailed 1973 Maryland Land Use Inventory is an expansion of the scheme used for the 1970 CARETS Land Use Inventory developed by Anderson et al. (171). The present classification scheme is designed for use with high altitude aerial photography and selective (minimal) use of collateral data. Mapping base, by Maryland counties, is 1" = 1 mile (1:63,360). Minimum size specifications for land use categories are:

A - No area will be recognized unless it is at least 10 acres in size; and

B - Units less than 530 feet wide will not be shown, except as acute corners of larger types, or extremely elongated cultural features. (The 10 acre minimum also applies to linear types).

DEFINITIONS

100 - URBAN AND BUILT-UP

110 - RESIDENTIAL - Single and multiple unit dwellings and yards and associated areas.

111 - Single Unit Residential - Detached, single family/duplex dwelling units.

A. Low SUR Density -
B. Medium SUR Density -
C. High SUR Density -

112 - Multi-Unit Residential - Attached single unit row housing, garden apartments with extensive common areas, high-rise apartment/condominium buildings.

A. Low MUR Density - not more than 3 stories nor more than 12 units/acre.
B. High MUR Density - more than 3 stories or with more than 12 units/acre.

113 - Mobile home and trailer parks and associated areas.

120 - RETAIL AND WHOLESALE SERVICES - Areas used primarily for the sale of products and services, including associated yards and parking areas.

121 - Retail sales and services (commercial).

Retail sales, services, and offices, including drive-in theaters, central business districts, neighborhood and regional shopping centers, and strip of roadside commercial developments, hotels and motels, and government (city, county, state, and federal) buildings (not including schools, churches, or cemetaries).

122 - Wholesale services and light industries - wholesale sales and services, including trucking companies and warehousing, and associated yards and parking areas. Also, light industrial and manufacturing facilities and parks including associated areas. Light industry includes manufacturing, construction, processing, and laboratory facilities other than those identified in heavy industry.

130 - INDUSTRIAL - Heavy manufacturing and industrial parks including associated warehouses, storage yards, research laboratories, and parking facilities, including the following types:

131 - Heavy Industries - heating processing, including primary metals industries and electric power generation.

132 - Heavy Industries - metal processing, including fabricated metal products and assembly.

133 - Heavy Industries - Chemical processing, including paper and allied products, petroleum refining, and petrochemical and chemical industries.

140 - EXTRACTIVE - Surface mining operations including sand and gravel pits, above quarries, and coal mines. Bare soil or tailings areas are considered part of this category. Status of activity (active vs. abandoned) is not distinguished.

141 - Coal (surface mines) - occur only in Garrett and Allegany counties, Maryland.

142 - Other Quarries and Pits - include sand, gravel, and stone.

150 - TRANSPORTATION, COMMUNICATION, AND UTILITIES

151 - Airports and associated features - Public and military airports, including runways, parking areas, hangars, and terminals.

152 - Railroads, including yards and terminals which meet minimum size (width) specifications.

153 - Freeways and highways, including interstate and multi-lane state highways, interchanges, and rights of ways which meet minimum size (width) specifications.

154 - Marine terminals - large commercial and military ports and associated facilities. This category does not swell, local marinas which are less than 10 acres.

155 - Utilities - water supply, sewage treatment, oil and gas delivery facilities, electric transmission stations, and telecommunication facilities.

160 - EDUCATIONAL (INSTITUTIONAL)

161 - Elementary Schools.

162 - Secondary Schools - Junior High and Senior High Schools.

163 - College and University - both public and private.

164 - Military facilities - built-up areas only, including buildings, storage, training, and other areas.

165 - Other Institutional - Includes churches, medical and health facilities, correctional facilities, and government facilities which may be identified as such from aerial photography or collateral data.

170 - STRIP AND CLUSTERED

Includes residential, commercial, etc. in small settlements and along transportation routes where separate land use categories cannot be delineated. Efforts are to be made to minimize occurrence of this category.

190 - OPEN AND OTHER (URBAN)

Urban areas whose use does not require structures or where areas of non-conforming uses have become isolated. Included are golf courses, parks and recreation areas (except areas associated with schools, etc.), cemetaries, entrapped agricultural and undeveloped land within urban areas.

200 <u>AGRICULTURAL LAND</u>

210 - CROP AND PASTURE LAND.

211 - Crop land - Land used to produce row, field, and truck crops such as corn, wheat, soybeans, and garden vegetables.

212 - Pasture land - land used for pasture.

220 - ORCHARDS - areas of bush and tree crops used for fruit production.

230 - FEEDING OPERATIONS - includes cattle feed lots (including holding lots for dairy animals), poultry houses, and hog feed lots.

400 <u>FOREST LAND</u>

The following descriptions apply to all sub-classes of forest land. These lands are at least 10% stocked with trees capable of producing timber or other wood products, and lands dedicated to forest production but temporarily cleared (i.e., logged). These lands include abandoned fields with woody brush that prevents classification as agricultural land.

Any lands that meet the above requirements and also those for a higher use category should be placed in the higher category.

410 - DECIDUOUS FOREST LAND

This class includes all forested areas in which the areas characteristically lose their leaves at the end of the growing season. This includes such species as: oaks, hickory, aspen, sycamore, birch, yellow poplar, elm, maple, cypress.

411 - Upland Deciduous Forest Land

This class includes those species that grow on upland, relatively well drained sites. This includes such species as: white oak, hickory, chestnut oak, aspen, cherry.

412 - Lowland Deciduous Forest

This class includes those species that occur on low moist sites, frequently poorly drained and may have intermitten standing water. This includes such species as: river birch, sycamore, red maple, sweet gum, ash, elm, tupelo.

420 - EVERGREEN FOREST LAND

This class includes all forested areas in which the trees are characterized by persistent foliage throughout the year. This includes such species as: white pine, loblolly pine, pond pine, hemlock, southern white cedar, red pine.

421 - Upland Evergreen Forest Land

Those lands classified are evergreen forests that occur on upland, relatively well drained sites.

422 - Lowland Evergreen Forest Land

Those lands classified as evergreen forests that occur on lowland, wet, poorly drained sites. These sites may have intermittent periods of standing water.

430 - MIXED FOREST LANDS

This class includes all forest lands in which deciduous or evergreen types do not predominate.

431 - Upland Mixed Forest Lands

Those lands classified as mixed forest lands which occur on upland, relatively well drained sites.

432 - Lowland Mixed Forest Lands

Those lands classified as mixed forest lands which occur on lowland, wet, poorly drained sites which may have intermittent periods of standing water.

440 - UPLAND BRUSH

This includes those lands classified as Forest Lands and do not produce timber or other wood products. These lands occur on relatively well drained, upland to rolling terrain. This includes such vegetation types such as sumac, vines, rose, brambles, etc.

500 WATER

510 - RIVERS - waterways, shown as linear features, which exceed minimum size (width) specifications.

530 - RESERVOIRS - Artificial water impoundments (Note: there are no natural lakes in the State of Maryland; all closed water bodies are by definition reservoirs).

600 NON-FORESTED WETLAND

This class includes all wetland areas with less than 10% forest cover woody vegetation.

610 - VEGETATED WETLANDS

Those lands classified as non-forested wetlands characterized by woody or non-woody vegetation.

620 - NON-VEGETATED WETLANDS

Those lands classified as non-forested wetlands with no predominate vegetation type that is persistent. This includes primarily tidal flats.

700 BARREN LAND

720 - BEACHES - extensive shoreline areas of sand and gravel accumulation. This category is not used if there is vegetation cover or another land use.

740 - BARE EXPOSED ROCK - areas of bedrock exposure, scarps, and other natural accumulations of rock without vegetative cover.

APPENDIX B

ERTS IMAGE DESCRIPTOR FORM

NOTE:

All ERTS imagery received were rated as "Excellent," "Usable," "Non-Usable" for application to land use/land cover analyses in Maryland. Criteria included cloud cover and overall image quality based on visual evaluation. Only those image sets rated as "Excellent" are included on this tabulation.

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY
D ______
N ______
ID ______

DATE 30 July 1974

PRINCIPAL INVESTIGATOR E. L. Thomas/ D. S. Simonett

GSFC ID 1261 AB

ORGANIZATION Maryland Department of State Planning/ Earth Satellite Corporation

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS* Coastal Plain	Fall Line	Mount.	DESCRIPTORS
1046-15301		X		River Mature Stream
1046-15304			X	Fold
1062-15190		X		Metropolitan Area Highway Bay Estuary
1079-15133	X			Bay Marsh (Coastal) Barrier Bar Inlet
1079-15140	X			Coastal Marsh Estuary Inlet Outwash Plain Bay
1080-15185		X		Mature Stream Pediment Trellised Drainage
1080-15192		X		Metropolitan Area Bay Estuary

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

MAIL TO ERTS USER SERVICES
CODE 563
BLDG 23 ROOM E413
NASA GSFC
GREENBELT, MD. 20771
301-982-5406

GSFC 37-2 (7/72)

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY
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N ______
ID ______

DATE 30 July 1974

PRINCIPAL INVESTIGATOR E. L. Thomas/ D. S. Simonett

GSFC ID 1261 AB

ORGANIZATION Maryland Department of State Planning/ Earth Satellite Corporation

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Coastal Plain	Fall Line	Mount.	
1096-15081	X			Sea Barrier Bar Inlet Coast Cirrocumulus
1096-15083				Coast Marsh Barrier Bar Coast Cirrus Altostratus Sea
1170-15193		X		Bay Metropolitan Area Estuary Snow Dendritic Drainage
1205-15141	X			Coastal Marsh Barrier Bar Bay Inlet Snow Coast
1205-15144	X			Coastal Marsh Bay Outwash Plain Estuary

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N
ID

DATE 30 July 1974

PRINCIPAL INVESTIGATOR E. L. Thomas/ D. S. Simonett

GSFC ID 1261 AB

ORGANIZATION Maryland Department of State Planning/ Earth Satellite Corporation

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS* Coastal Plain	Fall Line	Mount.	DESCRIPTORS
1260-15201		X		Metropolitan Area Bay Cumulus Estuary Highway Meander
1260-15195		X		Mature Stream Pediment Trellised Drainage Cirrus
1297-15252			X	Fold Mature Stream
1297-15254			X	Fold Meander Pediment
1312-15085	X			Barrier Bar Coastal Marsh Sea Altostratus
1313-15134		X		Mature Stream Metropolitan Area Highway Cumulus Consequent Lake
1314-15195		X		Metropolitan Area Estuary Bay

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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ORGANIZATION Maryland Department of State Planning/ Earth Satellite Corporation

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS* Coastal Plain	Fall Line	Mount.	DESCRIPTORS
1348-15082	X			Coastal Marsh Barrier Bar Cirrus Sea
1349-15134	X			Bay Barrier Bar Coast Line Marsh Estuary
1350-15192		X		Metropolitan Area Estuary Highway Bay
1385-15134	X			Estuary Marsh Bay Outwash Plain
1385-15131	X			Bay Marsh Barrier Bar Coast Line Dendritic Drainage
1405-15235			X	Fold Mature Stream Cirrus

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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GSFC ID 1261 AB

ORGANIZATION Maryland Department of State Planning/ Earth Satellite Corporation

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS* Coastal Plain	Fall Line	Mount.	DESCRIPTORS
1584-15152	X			Estuary Outwash Plain Mature Stream Dendritic Drainage
1566-15144		X		Mature Stream Pediment Trellised Drainage Snow Fold
1566-15151	X			Bay Estuary Marsh
1566-15153	X			Bay Estuary Outwash Plain Dendritic Drainage
1584-15145		X		Bay Estuary Metropolitan Area Highway Marsh
1674-15131	X			Estuary Mature Stream Outwash Plain Piedmont

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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APPENDIX C

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APPENDIX D

PAPERS, SYMPOSIA, & MEETINGS

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American Society of Photogrammetry 38th Annual Meeting, Falls Church, Virginia, March 12-17, 1972.

Earth Resource Technology Satellite-1 Symposium, Goddard Space Flight Center, Greenbelt, Maryland, September 29, 1972.

American Society of Photogrammetry Fall Convention at Columbus, Ohio, Falls Church, Virginia, October 11-14, 1972.

Seminar presentation to Western Maryland Regional Planning Office and local planning representation, November 15, 1972.

Special Committee on the Preservation of Agriculture Land, July, 1973 to Present.

Land Use Seminar; University of Maryland, July 5, 1973.

Maryland Association of Soil Conservation Districts, July 19, 1973.

Maryland Association, County Officials Annual Summer Meeting, August 24, 1973.

Meeting with Lance Marston and staff, Office of Land Use and Water Planning Department of Interior, September 24, 1973.

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Symposium on Machine Processing of Remotely Sensed Data, Purdue University, West Lafayette, Indiana, October 1973.

American Society of Photogrammetry Symposium at Sioux Falls, South Dakota, Falls Church, Virginia, October 29 - November 1, 1973.

Third Earth Resources Technology Satellite-1 Symposium, Goddard Space ~~Flight Center, Washington~~, D.C., December 10-14, 1973.

First International Joint Conference on Pattern Recognition, Washington, D.C., November 1973.

Study Commission on Intergovernmental Relations in Land Use Planning, January 3, 1974.

Fourth Annual Symposium on Automatic Imagery Pattern Recognition, Washington, D.C., January 1974.

A series of 42 meetings were held with local government officials and citizens to discuss data and methodology of the land use planning effort, January through February, 1974.

Meeting with Governor and Legislative Leadership on Land Use Planning Progress, February 25, 1974.

Maryland Regional Affairs Council, February 27, 1974.

"Technology Applications in Land Use Monitoring presentation to the Rural Land Use Institute sponsored by the American Institute of Urban and Regional Affairs and the Maryland Montgomery County Farm Bureau, Gaithersburg, Maryland, March 16, 1974.

Southern Maryland Realtors Association Conference, March 21, 1974.

Meeting with Baltimore Regional Planning Council and Planning Directors, October 18, 1974.

Land Use Data Meeting, U.S. Geological Survey, October 23, 1974.

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Denton Soil Conservation District Meeting, November 14, 1974.